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Editor: JOHN M. COULTER

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THE
BOTANICAL GAZETTE

JUNE 1911

CELL AND NUCLEAR DIVISION IN CLOSTERIUM

B. F. LUTMAN

(WITH PLATES XXII AND XXIII AND ONE FIGURE)

Historical

The first figures showing division in desmids were those of *Cosmarium* by EHRENBERG (**11**). Those drawings, while not entirely accurate, indicate clearly that he saw the two new daughter half-cells being interpolated between the old ones. Each half of the parent cell was evidently considered by him as an individual, since his genus description states that the individuals are arranged in the colonies "in chains of two or four."

NÄGELI (**33**), RALFS (**35**), and FOCKE (**17**) observed cell division in the desmids and gave fairly complete accounts of the process. DEBARY (**9**) did not describe division in detail, but mentions the fact that the newly formed transverse wall of *Closterium* and *Penium* is flat, and that the new end grows out as a cone-shaped structure. As the chromatophore is divided into two parts, some of the older observers, as EHRENBERG, regarded the mature plant as a chain of two cells, but DEBARY was clear on this point and recognized the desmid as a single cell with a nucleus between the halves. Nothing was observed by any of these investigators as to the conduct of the nucleus during division, as the importance of that organ of the cell was not yet fully recognized.

It is to ALFRED FISCHER (**14**) that we owe our first knowledge of the details of the process as it occurs in this genus. FISCHER found the cross-wall formed in essentially the same manner that STRASBURGER had described for *Spirogyra*. It appears soon after

nuclear division, at the middle of the cell at the point where the old nucleus lay, and cuts across the cell at right angles to its long axis. It is only after the complete isolation of the two halves of the old cell that the new ends of each *Closterium* grow out again to restore the symmetry of the chromatophore and cell outline in each individual. In each new end there lies a dense accumulation of cytoplasm, and in this is the daughter nucleus. FISCHER saw that immediately after nuclear division the daughter nuclei move back from the position occupied by the mother nucleus. They migrate out at right angles to the long axis of the cell, and move back from the equator of the cell to their new position in the forming furrow of the chromatophore. FISCHER watched this process eight times in living specimens of *C. Delpontii*, and found that the migration is a very rapid one and may occur along either the convex or concave side. In *C. Delpontii* this migration had frequently been completed before the two cells had pulled apart, and in *C. moniliferum* the nucleus frequently came to rest in the furrow in the chromatophore before that body had been entirely divided, the latter part of the process seeming to be completed under its direction. In the passage backward around the chromatophore the nucleus seems to press that body to one side to make room for it to pass. The granular protoplasm that had gathered at the middle of the mother cell forms the tip of each new half, and apparently assists as MOLL'S embryonic substance in the very rapid growth of the new membrane. This new half rounds out, the protoplasm streams into it, and the plant soon takes on a symmetrical shape. The new end vacuole appears in the granular tip, which even in the adult remains without chlorophyll. In *C. Delpontii* the entire process, beginning at about midnight, was completed and the two halves had become symmetrical in about five hours. FISCHER points out the further interesting fact that in the young *Closterium* the chromatophore in either end grows so that the two halves become pressed on each other, forming an apparent, but of course not real, fusion, as the two halves of the chromatophore remain separate throughout the life of the individual. He also noted that these observations on cell division give the reason for the conformity of the ridges of the chromatophore on either side of the nucleus.

FISCHER (**15**) in a later paper gave further details as to the origin in the new half of the end vacuoles and its crystals. He believed that the latter formed in the cytoplasm and later migrated into the vacuole.

Some of FISCHER's observations on the method in which the cell wall divides were criticized by both GAY (**18**) and HAUPTFLEISCH (**23**). GAY's paper I have not seen, but according to HAUPTFLEISCH, who reviews it, he points out that FISCHER's results hold only for wall division in those varieties with thick walls on which were longitudinal and cross-markings. HAUPTFLEISCH showed further that in those forms without girdle rings, such as *C. Ehrenbergii* and *C. moniliferum*, the isolation of the daughter cells is accomplished by a simple splitting of the cross-wall.

Considerable work has been done by LÜTKEMÜLLER (**26**) on the formation of the cell wall during the division process, but as little of his work has direct bearing on division in the species discussed in this paper, it will not be reviewed. Based on this work, LÜTKEMÜLLER has attempted to formulate a consistent scheme of phylogeny for the desmid group. He regards them as degenerate filamentous conjugates. This view he shares with WEST (**46**), who, as a result of studies on variation in desmids, had published an almost identical theory of their phylogeny three years previously.

The very peculiar nucleus of the desmids was evidently a puzzle to the early observers. DEBARY (**9**) does not attempt to describe it, but BRAUN (**5**) has the following to say: "The nucleus, with its colorless mucilaginous envelope, is maintained in the center of the spindle-shaped cell by the green lamellae of contents, arranged radiantly around the long axis of cell, which lamellae are interrupted by it in the middle of the cell." From this it will be seen that he evidently regarded the central granular mass as the nucleus, while the nuclear reticulum was the "mucilaginous envelope."

I have described (**27**) the resting cell of *Closterium* with special reference to the chromatophore and pyrenoids, but have given also briefly some idea of the peculiar structure of the nuclei in *C. Ehrenbergii* and *C. moniliferum*. The particular feature to which I called attention was the great accumulation of stainable material

at the center of the nucleus, which seemed to take the place of the nucleus or nucleoli of other plants.

All of this work on *Closterium*, with the exception of my investigation, it will be noted has been done either on the living cells or on fixed and stained whole mounts. The only members of the Conjugatae that have been studied with reference to cell and nuclear division in sectioned material are *Spirogyra* and *Zygnema*. Many investigators, on account of the ease with which the nuclear process can be followed in the filament, have preferred to use fixed and stained but unsectioned filaments, but others have resorted to sectioned material as the best means for seeing the finer details of the nuclear phenomena.

In *Spirogyra*, as is well known, the nucleus contains one or more nucleoli that are proportionally exceedingly large. On account of the great mass of nucleolar material, it has been generally accepted that the network outside the nucleoli either was very poor in chromatin or was entirely free from it, the entire chromatic material being concentrated in the central bodies which have been termed the chromatin nucleoli. A dispute has centered around the origin of the chromosomes; whether they came from the reticulum around the nucleolus or from the nucleolus itself. From the time when STRASBURGER (**37**) first investigated divisions in *Spirogyra* to the latest paper by KARSTEN (**25**) on divisions in the young plant as it comes out of the zygospore, the opinions of the investigators as to the origin of the chromosomes have been divided. Altogether over twenty papers have appeared on the subject, making the nuclear divisions of *Spirogyra* the most thoroughly studied of those of any algal form.

In STRASBURGER'S original contribution, which appeared in *Zellbildung und Zelltheilung* (1875), he claimed that the nucleolus or nucleoli by first falling into granules, which arrange themselves at the middle of the spindle, form the plate. This view he modified in 1882 (**37**) when he returned again to the study of *Spirogyra*, then arriving at the conclusion that in the species he was studying (*S. majuscula*) there was a nuclear cavity, the ends of the chromatin loops being at the poles of the spindle. This structure forms the equatorial plate, the nucleolus in the meantime having disappeared

and its substance having been used up probably in the formation of this spireme. After metaphase the chromosomes form two new spiremes, one at either pole, in the midst of which the nucleoli reappear. In 1884, in *Spirogyra nitida*, STRASBURGER (**38**) observed that the spireme appeared close to the nucleolus, which as a result seemed to take on a granular corroded appearance. In his paper in 1888 (**39**) he finds that in *Spirogyra polytaeniata* a typical spireme, gradually becoming denser, is formed in the nuclear reticulum, while the nucleolus disappears about the end of its formation. Twelve chromosomes are formed, which during the telophase form new spiremes and become reticulated. In other words, at this time in this species of *Spirogyra*, STRASBURGER believed that the nucleoli do not behave very differently in mitosis from those of higher plants.

FLEMMING (**16**) considered the spireme to be formed partly from the material in the nucleolus which became arranged in it. The achromatic part of the reticulum is utilized in the formation of the spindle. TANGL (**41**) claimed that the equatorial plate arose directly from the nucleolus, while CARNOY (**6**) believed that all the chromatic material in the nucleus was collected in the nucleolus, forming there a still smaller body which he proposed calling the nucleo-nucleolus. The nuclear cavity surrounding this body was empty. MEUNIER (**30**) confirmed these observations, finding a spireme formed inside the nucleolus in the early prophases. In the reconstruction stages the achromatic basis of the nucleolus is established first, and then on this the chromatic substance is deposited.

ZACHARIAS (**48**), as a result of microchemical tests, considered the nucleolus as pure plastin and similar to that of the higher plants.

DEGAGNY (**7**) in 1890 believed that while there was chromatin both in the nucleolus and in the extra-nucleolar part of the nucleus, it was the nucleolus alone that formed the plate. In later papers, however, he changed this opinion, and derived the plate from the spireme which comes to envelop the nucleolus closely and seems to absorb the substance from it.

Both MOLL (**32**) and MITZKEWITCH (**31**), applying modern

cytological technic and using microtome sections, arrived at the conclusion that practically all the chromatin was centered in the nucleolus. MOLL found the chromatin coming out of the nucleolus, leaving the latter empty. This chromatin then formed a spireme which cut up into 12 chromosomes. MITZKEWITCH found in the nucleolus two constituents, chromatin and linin. The chromatin appeared in the early prophases of division in the form of a definite number (24) of bodies imbedded in a mass of more lightly staining linin. This mass occupies the position formerly held by the nucleolus, and apparently seems to have resulted from its transformation.

VAN WISSELINGH (**42, 43, 44**), by a process of progressive digestion of the various parts of the nucleus by 40 per cent chromic acid, came to the conclusion that the nucleolus contains chromatin. He also found chromatin in the surrounding reticulum. He ascribed the origin of only two of the chromosomes to the nucleoli; if there are two nucleoli one chromosome comes from each; the other ten arise from the nuclear reticulum.

BERGHS (**2**) has recently devoted a very long paper to a detailed account of the process as he finds it in a *Spirogyra* which he believes to be *S. nitida*. He finds all of the 12 chromosomes arising from the nucleolus, the reticulum surrounding it being entirely free from chromatin. After the chromosomes are formed, there still remains in the nucleolus a second substance which stains less deeply. This substance divides transversely into two groups of pieces which move to the poles with the chromosomes. The nucleus is reconstructed out of these two substances, which, after undergoing vacuolization, are condensed in the nucleolus.

KARSTEN (**25**) finds in the first division of the fusion nucleus in the zygospore of *Spirogyra jugalis* that 14 tetrads arise from the nucleolus, which lies surrounded by light plasma containing two or more weakly staining chromatin spheres, apparently comparable to the extruded nucleoli of other plants. He has followed the development of these chromosomes and finds them appearing gradually in the dark stained nucleolar mass. This stage he believes to be comparable to synapsis in the higher plants.

Miss MERRIMAN (**29**) finds in *Zygnema* a central body which

apparently gives rise to part of the chromosomes, the remainder coming from extra-nucleolar granules. In these opinions it will be seen that she agrees with the results of VAN WISSELINGH (**43**) on *Spirogyra*. At no time did she find a spireme formed. In the telophase, part of the chromosomes, the number apparently not having been determined, fuse to form this central body (nucleolus), while the remaining ones are distributed throughout the nuclear cavity as granules.

ESCOYEZ (**12**) has also recently studied *Zygnema* in GRÉGOIRE'S laboratory, and has arrived at quite different conclusions from those of Miss MERRIMAN. While the nucleolus is very large, the nuclear reticulum furnishes all the chromosomes. He does not deny the fact that the nucleolus may supply some of the chromatic material, but is certain that the morphological chromosomes do not come from it. He finds the chromosomes to arise, not by the fusion of granules as Miss MERRIMAN describes, but in the form of slender rods. In the telophase, the nucleolus is not formed by the union of the chromosomes at the center, but appears to arise independent of the chromatic reticulum.

The spindle in *Spirogyra* is believed by STRASBURGER (**39**), MITZKEWITCH (**31**), VAN WISSELINGH (**44**), and BERGHS (**2**) to be purely of cytoplasmic origin, while MEUNIER (**30**) thinks it to be partly so. On the other hand, FLEMMING (**16**) believed it to be derived from the nucleus itself. Miss MERRIMAN (**29**) seems to favor the view that the spindle arises intranuclearly in *Zygnema*. ESCOYEZ (**12**) believes that in *Zygnema* it is formed from the cytoplasm, although he has not followed the process in detail.

The very peculiar bodies, nucleolus or some structure corresponding to it, that are present in the resting nucleus of *Closterium*, I have described in my previous paper (**27**). On account of the importance of the question as to the behavior of these bodies in nuclear division, especially with reference to the theories of inheritance, which makes the chromatin or the chromosomes the special idioplasm, it will be well to notice some of the recent opinions relating to the rôle of the nucleolus in the formation of the chromosomes, especially in the higher plants.

WAGER (**45**) has recently quite thoroughly reviewed the litera-

ture on that subject, and has expressed some opinions of his own derived partly from the facts as they have been presented by various observers and partly as a result of his work on nuclear division in the root tip of *Phaseolus*. He arrives at the conclusion that the nucleolus is not an independent organ of the cell, but only a part of the nuclear thread in which a considerable portion of the chromatin may be stored, and from which it may be withdrawn again at the time of chromosome formation. He agrees with DIXON (**10**), therefore, that if the chromatin is the bearer of the hereditary qualities, not only the chromatin granules but also the nucleolus must be taken into account in any theories on the subject.

In a number of other plants outside of the Conjugatae the nucleolus has been reported as containing the larger part or all of the stainable material in the nucleus. GOLENKIN (**19**) finds in *Sphaeroplea* the nucleolus breaking up directly into chromosomes. WOLFE (**47**) describes all the chromatin in the *Nemalion* nucleus as being stored in the nucleolus. BEER (**1**) says that the nucleolus of the cells of the *Riccia* thallus contain practically all the chromatin. He was able also at times to distinguish in it a composite structure, as though it were composed of granules. He believes that the spireme thread becomes thickened by the material from these granules. He also believes that similar conditions are found in one of the mosses (*Funaria*).

ESCOYEZ (**12**) states that the nucleolus in *Stypocaulon* appears to contain the larger part of the chromatin, as the reticulum around it stains very lightly in the iron-alum-hematoxylin. The chromosomes are formed from the reticulum, however, and in the telophase the chromosomes form again a typical reticulum, the nucleolus not being formed by their fusion.

STRASBURGER (**40**), as a result of the fact that he finds in *Marsilia* practically all the stainable material collected in the nucleolus, draws the conclusion that the linin and not the chromatin may be the bearer of the hereditary qualities, while the division of the chromatin is only a device to equalize the food supply of the cells.

The very discrepant accounts of *Spirogyra* given by different investigators, and the very close relationship of *Closterium* to it, make a study of the latter very desirable, especially in view of the

very peculiar structure of the nucleolus as I have previously described it (**27**). If the chromosomes fuse together in the telophase of the divisions of the Conjugatae to form a large central body or bodies, this ought to be a favorable place to find them, for this mass is certainly a composite one.

This work was begun at the University of Wisconsin under the direction of Professor R. A. HARPER, but was completed after leaving his laboratory. I am since greatly indebted to him, however, for his critical reading of the manuscript of this paper and for his suggested changes.

Methods

I have already described in my previous paper (**27**) my method for fixing, imbedding, and sectioning *Closterium*, and will only refer briefly to it here. As had happened in the two preceding years, the lily tanks in the botanical greenhouse at the University of Wisconsin were rapidly becoming covered with *Closterium* on the bottom and sides in the early part of May 1909, the organisms occurring in such abundance that they could be obtained in quantity and under favorable conditions for the study of their asexual reproduction. They have regularly disappeared from the tanks during the winter, whether due to the water becoming cold or from their going into the resting condition could not be determined, but they have just as regularly begun to appear again in quantity about the middle of April. The first series of fixations was made the night of May 2, beginning at 11 P.M. and continuing hourly from that time until 5 A.M. Four other series were fixed during the month of May. It was found that the early stages of chromatophore and nuclear division occurred more frequently early in the evening, even as early as 9 P.M., so the major part of my work has been done on material obtained from that time until midnight. The time of the maximum number of divisions is undoubtedly dependent on the character of the preceding day, whether cloudy or bright, determining the amount of starch stored, and more especially on the temperature of the water, although no accurate observations were made on these factors.

The physiological condition of the individual plants also determines their ability to divide, the particular condition required

being apparently a chromatophore filled with large quantities of starch. The difference in external appearance between those cells which are dividing and those not dividing is very striking; the individuals whose pyrenoids only showed a thin shell of starch and in whose pale green chromatophore there was practically no stroma starch were never found dividing, while those whose pyrenoids were surrounded by thick pieces of starch and whose dark-green chromatophore contained an abundance of free starch were the ones found in division.

Fixation was in Flemming's weaker solution, half-strength, although other fluids were used. This solution caused some shrinkage, but as this was principally in the ends of the chromatophore, it did not affect the phenomena of the nuclear and cell division that were occurring principally at the middle of the cell. When the organisms had been brought into the paraffin in which it was desired to cut them, the previous changes of alcohol, paraffin, etc., having been made by pipetting off the liquid above the *Closterium* lying at the bottom of the vial, the vial containing them was held in ice water for a few minutes. The glass could then be broken away and the layer of paraffin containing the plants sectioned. Staining was largely with the triple stain, although iron-hematoxylin was used to a limited extent. After fixation in the Flemming solution all the nuclear and cytoplasmic structures take differential staining very easily.

In addition to the sectioned material, whole amounts were stained with iron-alum-hematoxylin, gradually transferred to glycerin from the water, and mounted in glycerin.

The same species, which I consider to be *Closterium Ehrenbergii* and *Closterium moniliferum*, whose vegetative cells were described in my previous paper (**27**), were found dividing. In my first series of fixations (May 2) both of these were very abundant, but in all my later attempts I succeeded in getting only *C. Ehrenbergii* in division in quantity, the *C. moniliferum* having in the meantime largely disappeared. As my later fixations were the richer in divisions and were the ones upon which I have depended for the larger part of my work, it was found possible to work out the process in all detail in sections in *C. moniliferum*, although I was able

to get a fairly complete series of stages of division in my whole mounts. Enough division figures were found in the sections, however, to assure me that the process was practically the same in the two species.

External appearance of the division process

FISCHER (**14**) has given a fairly complete description of the process of division as it can be seen both in the living specimens and in stained whole mounts, but in order to understand the structures and phenomena that are found in the sections it was necessary to restudy the whole process in detail, according to FISCHER'S method. It will be remembered, too, that owing to the density of the chromatophore and the granular nature of the cytoplasm, FISCHER was able only to guess at the nuclear changes that were occurring simultaneously with those seen in the cytoplasm. Further, it is practically impossible with whole mounts to discover the details of the method by which the new cross-wall is put across the old cell.

Many species show parts of several generations in their cell walls. LÜTKEMÜLLER (**26**) has made a careful study of a number of these species and genera. In both *C. Ehrenbergii* and *C. moniliferum*, however, the process is a very simple one, and the wall, which is very thin and without markings, does not permit the distinction of the parts belonging to different cell generations.

The first external appearance of division in an individual is a pinching in of the chromatophore about a third of the distance from the middle to the tip (figs. 1–9). As previously noted, this occurs only in individuals that have their dark green chromatophores well filled with starch. This pinching in affects at first only the ridges of the chromatophore and occurs inside the plasma membrane, which becomes pulled away from the chromatophore. The mechanics of this process is difficult to understand. It is plain that the division of the chromatophore is entirely distinct from that of the cell. It has the appearance of being constricted as by a rubber band around it at this point. The division of the chromatopore in *Spirogyra* and other Conjugatae is described as due to the constriction of the entire cell. The chromatophore here would

seem to divide just as the entire cell divides in animals like the amoeba, but the constriction in these animals, it must be noted, is a constriction of the plasma membrane. In the present case it may be due to the constriction of a membrane forming the outer layer of the chromatophore, which may perhaps be regarded as similar to a thin tonoplast bounding a vacuole. Progressive cleavage such as HARPER (**21**) has found in the sporangia of the fungi and slime molds, in which the mass of protoplasm is cut up by irregular cleavage furrows from the surface and from the interior, of course corresponds to the cell division and not to the division of the chromatophore in *Closterium*. The furrows in the sporangia are scattered throughout the cleaving mass, being perhaps due to an extrusion of water from its surface and interior, while in *Closterium* there is only one furrow, and this is localized in a definite zone at the middle of the cell. No nuclear changes are visible at this time, and any theories that connect nuclear division directly with cytoplasmic division, such as those of HEIDENHAIN and KOSTANECKI, would seem to break down in the present case.

The nucleus, in the meantime, has apparently undergone no change that is visible externally (figs. 1, 9), the granular mass at the center being still present. The nucleus is in the process of spireme and chromosome formation during the time the chromatophore is dividing, although this process is not visible externally. Soon, however, some individuals (fig. 2) show the chromosomes in the equatorial plate stage on a cylindrical spindle whose ends are hidden by the projecting chromatophores. The nucleus now apparently disappears (fig. 3); the chromosomes, being drawn back to the ends of the spindle, are under the ends of the chromatophore and cannot be seen. Across the middle of the cell there is now (fig. 3) a very conspicuous broad band of granular matter, in the middle of which the new wall is put across. The two nuclei, having been reconstructed, can then be seen moving out to the surface of the chromatophore and making their way back (fig. 4), immediately under the plasma membrane, to the new position they are to occupy permanently in the new cell at the middle of each chromatophore. FISCHER (**14**) states that these migrations

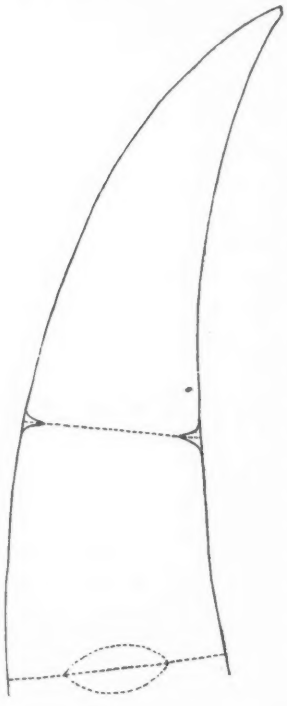
occur on both the concave and convex sides, but I have found them in these species to be practically all on the convex side.

The movement of the nuclei is apparently amoeboid, comparable to that of the male nucleus of the flowering plants in its progress toward the egg nucleus in the embryo sac. In the present case, however, it seems conceivable that the pushing outward of material into the new end of either daughter *Closterium*, combined with the change of shape which that end undergoes as soon as the new wall is formed, may assist to some extent in the movement of the nuclei. It will not explain it entirely, however, and we are forced to assume some stimulus that induces the nucleus to move to its new position. As long as the nucleus is at the end or along the side of the chromatophore, the two sides of the nucleus are exposed unequally to the food supply, and while the active streaming movements in the peripheral granular layer would partly equalize the deficiency, the side that is next the chromatophore is in touch with the soluble foods that are available there in greater quantity than at the side next the granular layer. The only way in which the nucleus can supply itself equally with food over its entire exterior surface is to imbed itself near the center of the chromatophore, and this is the position of course which it finally assumes. Other stimuli may of course also be in play.

Soon after the new cross-wall is put in at the middle of the desmid, the new end begins to round out, but the two organisms hang together for quite a time, with only a very slight connection (figs. 5, 6, 10). The connection finally breaks and the individuals separate before the new halves are at all symmetrical with the old ones (figs. 8, 12). The granular material which formed a band across the cell now makes a thin cap for each new half (fig. 6), the material in it being continuous with the plasma membrane and forming a conspicuous example of MOLL's embryonic substance. The change of form of this new end, resulting in an organism with symmetrical chromatophores, and the formation of the end vacuole in the granular portion follow slowly (figs. 8, 11, 12, 13). The process as we can see it, while superficially an apparently very simple one, is extremely difficult of explanation in terms of physics

and chemistry. It would seem to be necessary to assume some sense of form in the organism which MOLL has named "morphaesthaesia," a striving of the individual to attain a certain shape characteristic for the species.

The apparently unequal division of the chromatophore attracted my attention, and in order to determine just what were the proportions of the dividing parts, I made careful camera lucida drawings of six individuals of *C. Ehrenbergii* in early stages of division. It will be seen from the text figure, which is a composite one made from these six sketches, that the chromatophore division results in a cone and a frustum, and that apparently the cone is much the larger. The cubic contents of these two solids can be approximately determined, however, and the rather surprising fact is revealed that the cone has certainly not more than two-thirds the cubic contents of the frustum. It must be remembered, however, that the frustum end includes half of the large nucleus and of the vacuoles on either side of it which do not appear in the cone end. This blunt end is also the one which must undergo reconstruction, a process which undoubtedly uses up quite an amount of material such as starch, of which this portion contains more than the cone. However, it is plain that it would be improper to speak of this new half as "growing out," in the sense that it has to grow in order to become as large as the pointed end. It contains at division as much, or probably more, material than the old end; there is a reshaping of this material, but both ends take part in the growth that is to produce again a normal size in the individual.



The nucleus in these two species seems to arrive regularly at the center of the new organism before the chromatophore has finished its division (figs. 5, 6, 8, 11). This confirms FISCHER'S (**14**) observation that the nucleus in *C. moniliferum* usually arrives at the constriction in the chromatophore before it is complete, and that the separation of the last strands is apparently finished under its direction.

The resting nucleus

As commonly figured in textbooks on the algae, such as OLTMANN'S, the nucleus of *Closterium* is a lens-shaped or cylindrical body lying between the two halves of the chromatophore at the middle of the plant and containing a granular mass at its center. *C. moniliferum* is the species most frequently figured, and in it the drawings frequently show the two halves of the chromatophore pulled back from each other, with the nucleus lying as a cylindrical structure, somewhat contracted at the middle, connecting them.

I have already given a partial account (**27**) of the interesting and suggestive structure of the resting nucleus, but in connection with the present work I have of course carefully examined again great numbers of nuclei, both in whole mounts and in sections.

The nucleus is very large for an alga, and presents almost as favorable an object for study as does that body in the majority of the flowering plants. There is quite a little difference in its structure in the two species studied, although in a general way they are very similar, and are both essentially like that of *Spirogyra*. The nucleus of *C. Ehrenbergii* is in the form of a biconvex lens (figs. 14, 15), and I have never found it losing this shape as a result of the two halves of the chromatophore pulling away from each other. In end view it is circular in outline, as shown in fig. 16.

The mass of the nucleus is made up of a very fine reticulum which stains very faintly both in the triple stain and in the iron-hematoxylin, and shows a few such chromatin granules as occur on the linin threads of many of the higher plants. If such granules are present, they must be very minute or do not retain the stain. There are darker staining places in the reticulum, but I should be inclined to regard these as net-knots rather than as definite bodies. At the center of this fine reticulum is a mass of substance

which stains intensely with the safranin in the triple stain. This body, or mass of bodies, seems to be composed of globules partly fused together, and has the position and presumably the function of the nucleolus in other plant cells. In this species of *Closterium* these bodies form an irregular accumulation at the center of the reticulum, usually, at least partially, fused together in various ways, sometimes in the form of a string of beads stretched across the long axis of the cell, while at the other times the chain may be coiled around on itself, so that it simulates a spireme or has the appearance of the chromatin in the cells of the salivary gland of the *Chironomus* larvae. As would naturally result from the partial fusion of spherical granules, the individual pieces are angular on some of their sides, while rounded on others. It is not possible to determine whether, in the living cells, these globules are separate or not, or whether the partial fusion is due to fixation, such as sometimes happens in the case of chromosomes. Owing to the very faint stain which the reticulum takes and the very small size of its meshes, it is not possible to make out with any degree of certainty its relation to the central bodies.

In *C. moniliferum* (figs. 17, 18) the nucleus is composed, as in *C. Ehrenbergii*, of a very delicate reticulum containing apparently very little chromatin in the form of granules. At the center of this reticulum is usually found a large, more or less angular body, which apparently represents the irregular mass found in *C. Ehrenbergii* and the nucleolus of other plants. This nucleolus, while not having the smooth, homogeneous, globular appearance of that body in *Spirogyra*, still does not have the irregularly diffuse structure it presents in the other species of *Closterium* which I have studied. The pieces, while fused together, do not seem to form a compact mass. It has an irregular outline and shows lighter and darker places, if not stained too densely (fig. 17). The condition here would seem to represent an intermediate condition in the fusion of the nucleoli between that of *Spirogyra* and that of *C. Ehrenbergii*.

Prophase

As the formation of the spireme apparently requires a long time for its completion, the prophase is one of the stages that can be

found in great numbers. This is especially important for the question here involved, as it is one of the critical stages in which the relation of the compound nucleolus to the spireme and the chromosomes should appear.

As with mitosis in all plants, it is difficult to determine just the point at which the spireme starts to be differentiated out of the nuclear reticulum which gives rise to it. The reticulum seems to become drawn out into strands (fig. 19), but the exact method by which this takes place is not clear, for, as previously noted, the meshwork is a very delicate one, which stains very faintly and in which the structures are all very minute. These first strands, like the reticulum from which they are derived, apparently contain little chromatin in the form of granules (fig. 17), although a few such bodies are scattered in it; as the spireme grows more definite, however, there appear in it numerous small bodies which stain more densely (fig. 20).

The compound nucleolus, in the meantime, retains its position at the center of the nucleus, but the partly fused masses that composed it now becomes separated into small spheres that are independent of each other (figs. 19–23). This would seem to indicate that during the process of spireme formation, at least a portion of this central body is used. This body is suspended in the nuclear reticulum in some manner, but further than that it is not possible to see any connection between the two, such as has been shown for nucleoli in some animal cells, and by WAGER (**45**) in the nuclei of the root tip of *Phaseolus*, in which he states that the nucleolus is really only a very large granule or sphere on the linin thread. In the case of *Closterium* this central compound nucleolus apparently lies entirely clear of the reticulum, but this is undoubtedly only apparent, as it would not retain its central position in the nucleolus if it were not attached. If part of the material forming this body does pass out to assist in forming the spireme thread, the passage must occur while it is in a liquid state or as very small spheres. There is of course the possibility that the small, darker staining bodies on the spireme thread (fig. 20) may have migrated out in this manner, but the point to be particularly emphasized is that there is no passing out bodily of large pieces of this compound

nucleolus to form chromosomes on the spireme, as the compound appearance of that body in *C. Ehrenbergii* especially would indicate might happen. There seems to be no question that this body loses part of its material during the time of spireme formation, as its diminished size clearly shows, but it is no more possible here than it is in the flowering plants to prove directly that it is used to form the spireme. The spindle fibers are being formed at either pole, and it is entirely possible, as STRASBURGER believes, that it may be utilized in their formation. The apparently small quantity of chromatin in the reticulum, combined with the small size of the chromatin granules observed on it as compared with the density and size of the spireme, would certainly lead one to suspect, however, that the material from the diminishing nucleolus was being transferred to it. Of one fact there can be no question, and that is that the substratum of the spireme itself arises in the extranucleolar part of the nucleus, and not, as MITZEKEWITCH, BERGH, KARSTEN, and others have found in *Spirogyra*, inside the nucleolus, and that while the relation of the nucleolar material to this structure may not be clear, it does not seem to differ essentially from that which is found in the higher plants.

The spireme cuts transversely into chromosomes, no previous longitudinal split having been found, although it probably occurs. At the time this segmentation takes place, the spireme thread still has an irregular outline, due to small projections from its surface. These projections appear (fig. 24) also on the chromosome at first, but later disappear, and the chromosomes become long rods with a smooth surface.

In the meantime the ellipsoidal nucleus is undergoing changes in shape. Its smooth outline is lost and the nuclear walls are drawn out in places (figs. 19–21). The walls (fig. 24) are very much thickened at the future poles of the spindle, and a dense layer of fibers lies outside of them, while the equatorial walls are thin and irregular. Some of the figures obtained at this time resemble somewhat those of HERTWIG (**24**) for *Actinosphaerium*, although the thickening in the present case is not so great as is shown in his end plates. Some of these fibers extend out and are apparently attached farther back in the chromatophore, evidently serving

to attach the broad ends of the spindle, when it is fully formed and functioning, as a sort of anchorage for it. As a result of my observations I am of the opinion that the spindle itself is largely of cytoplasmic origin. The actual ingrowth of fibers which take hold of the chromosomes and later pull them apart was not observed. Strands of a lighter staining substance, probably what has been considered linin, connect the chromosomes to each other and to the nuclear wall (fig. 24). All that would seem to be necessary to form the attachment to the chromosomes would be a strengthening of those fibers extending to the nuclear wall. If this be true, there should be no fibers growing into the nucleus from the outside to take hold of the chromosomes, but only a thickening of those already present.

Metaphase

The spindle (fig. 25) is broad and as wide at the poles as at its middle. No bodies in the nature of centrosomes occur at the poles, which are broad and platelike structures (fig. 25) very similar to those described for *Spirogyra*. There are occasionally spherical bodies found in this region (figs. 28, 29), which may be metaplasmic particles, or perhaps the remains of the old nucleolus, although this point was not worked out. The spindle is attached by fibers extending from it, especially at the two sides. It is not possible to determine just where the spindle ends (figs. 25, 26). In the equatorial plate are arranged the rodlike chromosomes (fig. 25). Attached to each chromosome are fibers from either pole which pull it into two parts by a longitudinal split (fig. 26). These fibers are in the figure attached toward the middle of the chromosome, although many were also observed in which the attachment was toward their ends.

Telophase

After the chromosomes have been pulled back to the poles (figs. 27, 28) in the usual manner, they lie there in the form of a plate which is more or less crescent-shaped in cross-section (figs. 29, 30). The broad central spindle remains connecting the two poles, but gradually disappears, taking no part in the formation of the new cell wall (fig. 30). The chromosomes at either pole

apparently unite end-to-end to form a dispireme (figs. 31, 32). The nucleus with the included spireme has originally the shape of the group of chromosomes in telophase, that is, a plate, and this is retained during the reconstruction stages. The spireme stains very densely at first (figs. 29–31) while it still retains all the chromatin, but later becomes so faint that it is difficult to see (fig. 32). The formation of the reticulum from the spireme cannot be followed with any great clearness on account of the small size of the parts. There is a reticulum formed (fig. 32) in some manner, however, and on it appear bodies which stain more densely than the meshwork by which they are surrounded. At first these bodies are small and numerous, but in the later stages (fig. 33) they have fused into masses of considerable size; these masses will later form the compound nucleolus. When the nucleus has been entirely reconstructed, these bodies still lie more or less scattered, and while the nucleus is making its way back to its new position (fig. 34) there are still usually at least two groups. Apparently it is only after it has come to rest at the middle of the daughter cell that all of these nucleolar bodies take their position at the center of the nucleus. The process, as will be seen from fig. 35, is essentially the same in *C. moniliferum* as in *C. Ehrenbergii* from which the other figures were drawn. In *C. Ehrenbergii* there is only a slight fusion in places, while in *C. moniliferum* it is sufficiently complete to make a fairly homogeneous structure.

After the nuclei have been reconstructed, they begin to move out to the surface of the cell (fig. 34) and then around the chromatophore. The chromatophore being evidently a very dense structure, it is apparently much easier to go around than to penetrate it. In *Spirogyra* the central part of the cell is almost entirely free from cytoplasm, and the daughter nuclei would meet no such obstruction. As previously noted, this migration occurs along the grooves of the chromatophore (fig. 7), where, as has been shown in my paper (**27**) on the chromatophore, there are fewer strands of cytoplasm to impede its passage.

As the nucleus in both species usually arrives at the new position some time before the chromatophore has finished its division, it is very common to find figures like nos. 6, 8, 11, and 36, in which

the final separation of the two halves seems to occur "under its direction." In sections, the relation of the plasma membrane to the vacuole which is cutting the chromatophore in two is brought out very clearly (fig. 36).

It is not possible to learn more of the movement of these nuclei in sections than it is in whole mounts. The process, however, seems to be some kind of an amoeboid one, judging from the changes in shape the nuclei undergo in the process.

The formation of the daughter cell walls

There seems to be a general agreement that in the Conjugatae the new cell wall arises by a growth inward from the old wall, in which the spindle fibers, unlike those of higher plants in which a cell plate is formed, take no part. The central spindle remains in place while the wall is growing (figs. 27, 29), but seems to take no visibly active part in its formation, although there is the probability that its material may be used up to form the new plasma membrane. It is to be noted further that none of the fibers of the central spindle persist (figs. 33, 34) until they are cut in two by the ingrowth of the wall from the sides, as occurs in *Spirogyra*.

The process of new wall-formation is essentially the same in the two species of *Closterium* studied as in *Spirogyra*. After the chromosomes have been drawn back to the two poles, the large central spindle, which previously had been very conspicuous, disappears, and in the later stages of the telophase all that can be seen of it are a number of fibers extending through the region it formerly occupied (fig. 29). The cross-wall begins to grow in during metaphase, the process starting at the periphery of the cell and seeming to be due to constriction of the plasma membrane. Preceding and also accompanying this growth of the plasma membrane a layer of granular cytoplasm appears, in which the streaming movements are very noticeable in the living specimens. The new wall cuts across the spindle fairly at its center, being a third of the way across by the time the fibers have disappeared. Connecting the two nuclei is a granular band which, connecting with the ingrowing plasma membrane, gives the appearance shown in fig. 3 to the external view of the whole mount. By the time the

nuclei are entirely reconstructed, the new wall is about two-thirds of the way across in section, and the nuclei move out to the surface of the chromatophore and are making their way back to their new position before the remaining part is closed (fig. 34). It would seem from this that the presence of the two nuclei is not required for the completion of the cell division, but that the material for the new wall is there and the process is well begun before they begin their migration. It will be particularly noted that the new wall is put in at right angles to the old side walls.

It is clear that the younger end of the new individual will be covered partly by the new transverse wall that is becoming pushed out into a cone (figs. 11–13) and partly by a portion of the old parent cell wall. Where these two portions meet, the so-called girdle band appears in certain species, but in the two forms under consideration it is soon difficult to distinguish the point of union of the old and new walls, although it can be seen in individuals recently divided (fig. 8).

General considerations

FISCHER (**14**) has already pointed out the fact that it is due to the method of origin of the daughter chromatophores by division that the ridges of the chromatophore on either side of the nucleus correspond, as each ridge was cut in two when the chromatophore divided. It is to be further noted that the division of the chromatophore also explains the continuity of the outer granular layer, in which the streaming occurs, across the region separating the two halves of the chromatophore. When the chromatophore is pinched into two parts, the constriction process takes place inside this granular layer, which is not divided, but is left intact to form the outer wall of the ring-shaped vacuole. In *Closterium*, as seen during the daytime, this granular membrane is still continuous, and in it occurs the very active streaming movement between the two parts of the chromatophore.

The time relation between the division of chromatophore and nucleus in these plants is an interesting one. *Closterium* as seen in the daytime has its chromatophore divided into halves. These two halves are the result of the chromatophore division of the

preceding night. In these species of *Closterium*, however, they are further to be looked upon as being a preparation for a division of the nucleus and cell the following night, providing it has been successful in storing enough food material to make the process possible. If the individual is not able to synthesize enough starch, the nuclear and cell division is not carried out, and the two-parted chromatophore is retained indefinitely. In these species of *Closterium*, cell and nuclear division is at least a two-night process: the first night the chromatophore divides, cutting in two the greater part of the cytoplasm, but still retaining a connection between the two parts by means of the granular peripheral layer; the second night the nucleus may divide and the new wall separate the cytoplasmic halves entirely by cutting through the granular layer.

The question of the relation of the nucleolus to the chromatin, especially in the division stages of that part of the nucleus, is still an unsettled one both for plants and animals, and it is one that comes sharply into the foreground in this study of the division of the nucleus of *Closterium*. It would seem probable that, if the globular and nearly homogeneous nucleolus of *Spirogyra* contains the entire mass of chromatin in the form of a condensed spireme thread, as MOLL (**32**), MITZKEWITCH (**31**), KARSTEN (**25**), and others have found, this much more strikingly compound nucleolus of *Closterium*, arranged occasionally so as to resemble a spireme, should represent the chromosomes aggregated into a central clump. That the chromosomes are really formed from the nuclear reticulum in *Closterium* is certainly very decisive as to their morphological independence. The spireme formed outside the compound nucleolus seems indeed to be poor in chromatin, and the probability of the nucleolar material being used in the formation of the spireme cannot be denied. This, however, is also in some degree the case in the nuclei of the higher plants, and we are bound to conclude that the relations of nucleolus and chromosomes are probably the same in all nuclei, in spite of the much discussed evidence for a chromatin nucleolus in the Conjugatae.

If the spireme really thickens by the absorption of liquid material derived from the nucleolus, this can hardly be regarded,

as WAGER (45) holds, as evidence for the idioplasmic nature of the latter. The growth of the chromosomes from one cell generation to the next is still too obscure a subject to permit the use of such an interpretation.

As noted above, STRASBURGER (40), as a result of his work on *Marsilia*, in which he found the nuclear reticulum very poor in chromatin while the nucleolus was very large, holds the view that the linin may be the bearer of hereditary qualities, while the chromatin is only a food substance which divides simultaneously. This hypothesis is of interest, and it may be admitted that the recent attempts of BOVERI (4), ROSENBERG (36), OVERTON (34), and others to show that the chromosomes are permanent organs of the cell may be interpreted in support of the theory that the linin substratum of the chromosome is its more essential constituent, while the visible and more conspicuous chromatin granules only serve as conveniently scattered food.

Of interest also in this connection is the recent attempt of GRÉGOIRE (20) to show that the nuclear reticulum is all one substance, with no differentiation into chromatin and linin. These two species of *Closterium*, and in fact the Conjugatae in general, might be regarded as having a nuclear reticulum composed of a single substance; still they are perhaps not the most favorable material on which to study this question.

The chromosomes do not come bodily out of the nucleolus of *Closterium*, but that structure disappears during the prophase as in other cells, and we have as yet only theories as to its fate. In the present case the theory based on the observations of MOLL (32), MITZKEWITCH (31), KARSTEN (25), BERGH (2), and others, that as in *Spirogyra* the chromosomes are included morphologically complete in the nucleolus, would not be of service in these species of *Closterium*. In like manner the observations of VAN WISSELINGH (43) on *Spirogyra* and of Miss MERRIMAN (29) on *Zygnema*, that a number of the chromosomes come out of the nucleolus, would not apply in the present case. While the evidence in *Closterium* is not at all complete, the conclusion reached by ESCOYEZ (12, 13) on *Zygnema* and *Stypocaulon* would seem to be most in line with my own observations. These are, that while

the chromosomes do not come morphologically from the nucleolus, there is a possibility that part of the material from that body goes to form them.

The relationships of the desmids to the other groups of the Conjugatae is a rather puzzling one. While the great majority of them are unicellular, the tendency to form filaments appears in such genera as *Cosmarium*, *Euastrum*, and *Staurastrum*. BESSEY (**3**) has gone so far as to divide the desmids on this basis into three tribes: Desmideae, cells in unbranched filaments: Anthrodieae, cells solitary, elongated, but at not all or only moderately constricted; Cosmarieae, cells solitary, broad, and deeply constricted.

WEST (**46**) in studying variation in desmids came to the conclusion that the group is a degenerate one derived from a filamentous conjugate ancestor, probably among the Zygnemaceae. On this basis of degeneration he claims to be able to explain many facts previously difficult of interpretation. He holds that this degeneration has developed the highly specialized morphological characters of the different groups, thus explaining their beauty and variety of form, and that with it too has gone hand in hand the loss of sexual differentiation of the conjugating cells. LÜTKEMÜLLER (**26**), as a result of his very careful study of the cell wall of members of the different groups of desmids, has arrived at practically identical conclusions as to their phylogeny.

The position of the young transverse wall in *Closterium* also seems to throw some light on this question of phylogeny. The new cross-wall is put in at right angles to the old walls in a manner that is not in any essential different from that of the filamentous Conjugatae such as *Spirogyra*. It is only as the cells separate and the pressure is relieved on one side of this wall that the shape changes. If the cells should not separate, a filament being formed, each cell of the filament would not be essentially different from a cell of *Zygnema* with its nucleus at the middle and a half of the symmetrical chromatophore on either side. While the pointed shape which the new end assumes is obviously a secondary and acquired character, in the ontogeny of the transverse wall, we would seem to have a bit of the phylogeny of *Closterium* repeated.

Summary

1. *Closterium* divides from 10 P.M. to 5 A.M., and the new half has become practically symmetrical with the old one by 9 A.M.

2. Division is dependent upon the storage of a considerable quantity of starch in the chromatophore and around the pyrenoids.

3. The chromatophore divides by a constriction located about a third of the distance out from the middle. This constriction is due to the enlargement of a ring-shaped vacuole under the plasma membrane.

4. The resting nucleus of *C. Ehrenbergii* is made up of a very fine reticulum carrying little if any chromatin in the form of granules. At the center of this reticulum is a large compound nucleolus made up of a number of partially fused nucleoli. The resting nucleus of *C. moniliferum* has essentially the same structure, but the nucleoli at the center are more completely fused.

5. The spireme is formed outside the nucleolus and apparently separate from it. During its formation that body breaks down, but it is impossible to decide whether its material goes to the spireme or is used up for some other purpose. No chromosomes come bodily out of the nucleolus as has been described for *Spirogyra*.

6. The spindle is cylindrical, with broad poles, much resembling that of *Spirogyra*.

7. In the telophase a dispireme is formed, and in this the nucleoli reappear as small spheres which later partially fuse to form larger masses.

8. The two daughter nuclei move around the chromatophore, between its ridges, apparently in an amoeboid manner, to their new positions.

9. The new end wall is put across in essentially the same manner as in *Spirogyra*, that is, by a growth inward from the periphery.

10. Division in these species of *Closterium* is at least a two-night process: the chromatophore divides the first night; the nucleus the second night.

11. The position of the young transverse wall would seem to indicate that the pointed ends are secondarily formed, and that *Closterium* was originally a filamentous alga, which has developed the habit of breaking up into single cells.

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BURLINGTON, VT.

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EXPLANATION OF PLATES XXII AND XXIII

All figures were drawn with the aid of a camera lucida; the majority of them with the Leitz $\frac{1}{16}$ achromatic objectives and eyepieces, and the others with the Zeiss 3 mm. apochromatics and compensating oculars. The approximate magnification is indicated after each figure. Figs. 1–13 are from whole mounts in glycerin, and are diagrammatic in that they do not show the slight shrinkage of cell contents due to fixation and transfer to glycerin. The other figures are all from sections 5–10 μ in thickness, stained with the triple stain, except fig. 29, which is from a slide stained with iron-hematoxylin.

C. Ehrenbergii

FIG. 1.—Chromatophore just beginning to show constrictions; ×300.

FIG. 2.—Nucleus in metaphase; transverse cell wall beginning; ×300.

FIG. 3.—Transverse cell wall nearly complete; nuclei not showing; ×300.

FIG. 4.—Transverse wall complete; nuclei moving back to their new position; ×300.

FIG. 5.—New ends beginning to round off; nuclei at constriction; ×300.

FIG. 6.—New end still further rounded; ×300.

FIG. 7.—Position of nucleus between the ridges of the chromatophore as seen from the convex side; ×300.

FIG. 8.—Individual with asymmetrical halves; the chromatophore not yet completely divided; the new tip beginning to assume its pointed shape; ×300.

C. moniliferum

FIG. 9.—First appearance of constriction in the chromatophore; pyrenoids dividing; ×550.

FIG. 10.—Individual with two halves just ready to separate; ×550.

FIGS. 11–13.—Various stages in the change of form of the new halves; fig. 11 showing pyrenoids dividing; fig. 11, ×550; figs. 12, 13, ×475.

C. Ehrenbergii

FIGS. 14, 15.—The resting nucleus in side view; ×1800.

FIG. 16.—Resting nucleus in end view: ×1800.

C. moniliferum

FIG. 17.—Resting nucleus in side view; ×1800.

FIG. 18.—Resting nucleus in end view; ×1800.

C. Ehrenbergii

FIG. 19.—First traces of spireme formation; ×1800.

FIGS. 20, 21.—Later stages of spireme; ×1800.

FIG. 22.—Detail spireme showing chromatin granules; ×1800.

C. moniliferum

FIG. 23.—Spireme; nucleolus breaking up; ×1800.

C. Ehrenbergii

FIG. 24.—Chromosomes formed; ×1050.

FIG. 25.—Metaphase; ×1050.

FIG. 26.—Detail of metaphase; ×2400.

FIG. 27.—Anaphase; ×1050.

FIG. 28.—Late anaphase; ×1800.

FIG. 29.—Telophase: spindle fibers still showing; ×1050.

FIG. 30.—Telophase; spindle fibers have all disappeared; wall touching remains of central spindle; ×1050.

FIGS. 31, 32.—Telophase; dispireme; nucleoli reappearing in fig. 32; ×2400.

FIG. 33.—Late telophase; nucleoli fusing to form large masses; ×1050.

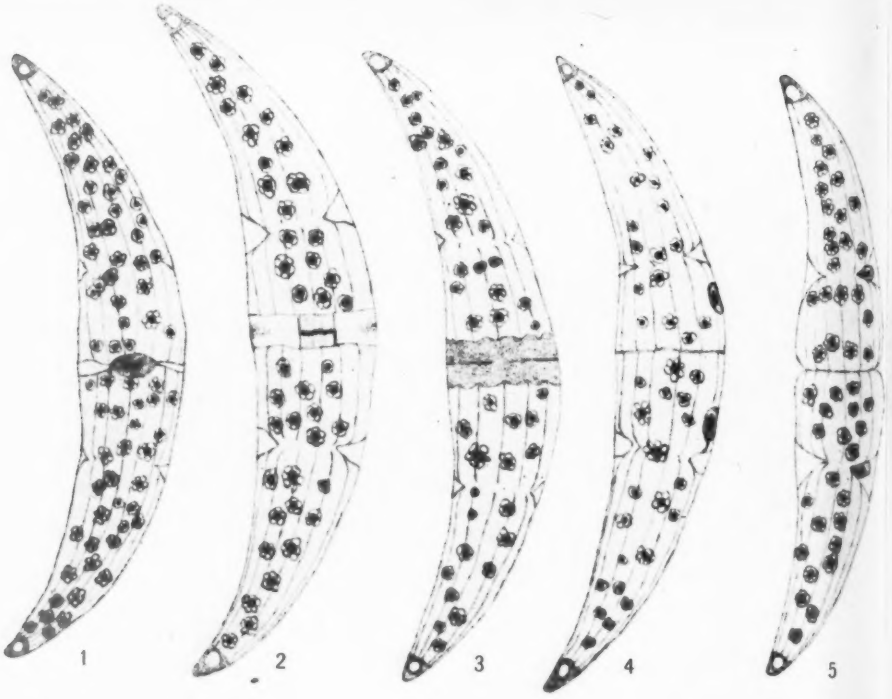
FIG. 34.—Nuclei moving out to surface of chromatophore; both nuclei still showing a number of masses of nucleolar material; cell wall not yet completed; ×1050.

C. moniliferum

FIG. 35.—Late telophase; nuclei reconstructed, but nucleoli not yet fused to form a single mass; cell wall beginning; ×1050.

C. Ehrenbergii

FIG. 36.—Nucleus in its new position at constriction in chromatophore, but latter not yet divided; *pp*, granular layer; ×1050.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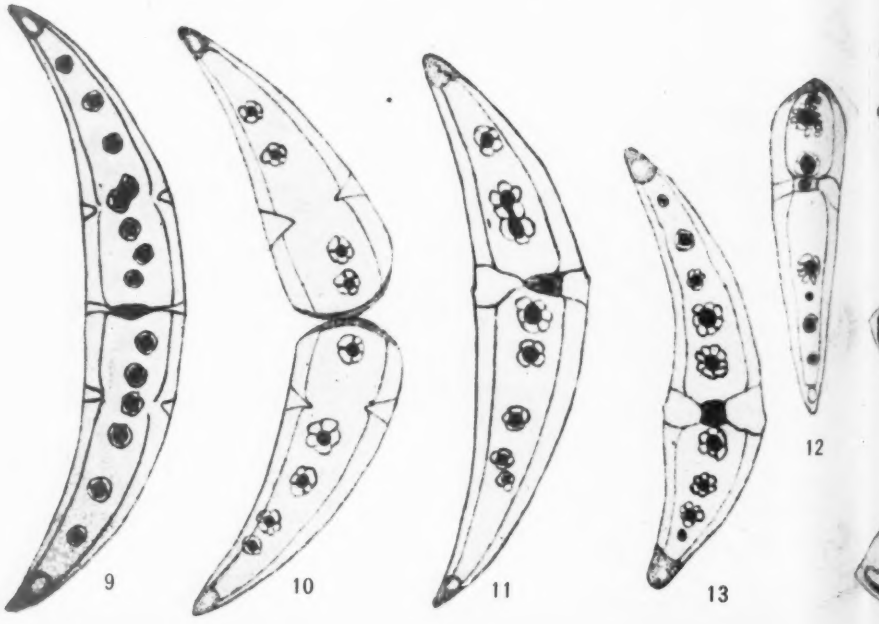
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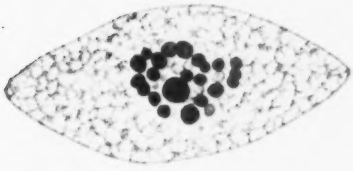

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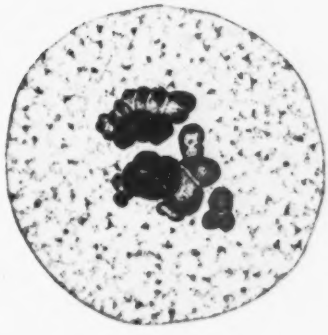

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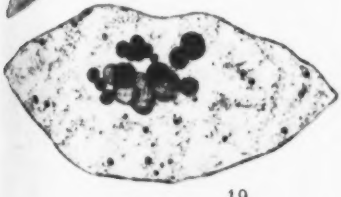

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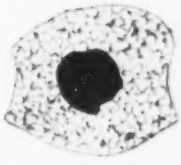

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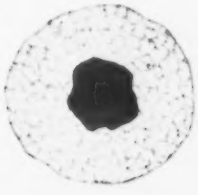

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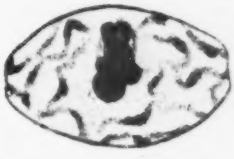

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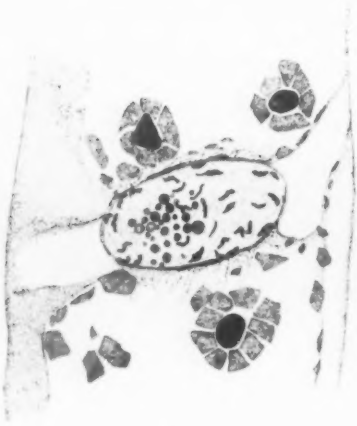
MAN ON CLOSTERIUM



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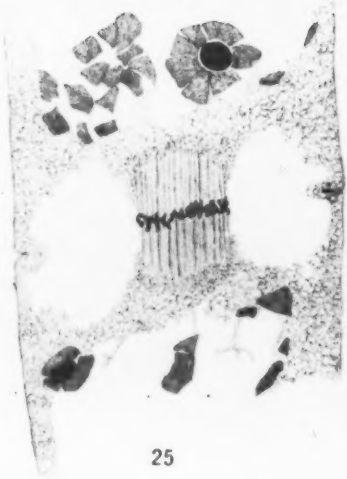

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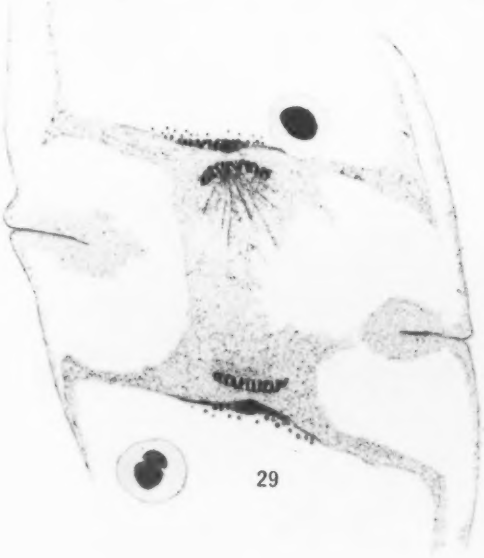

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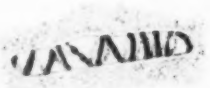

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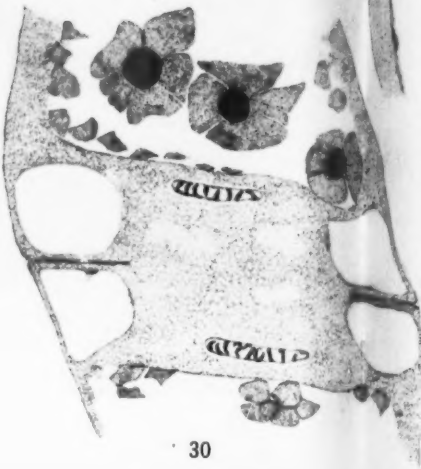

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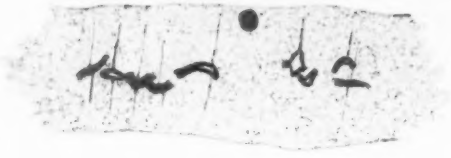

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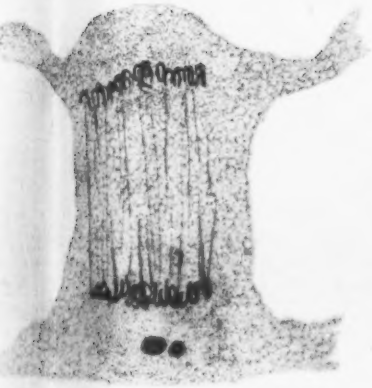

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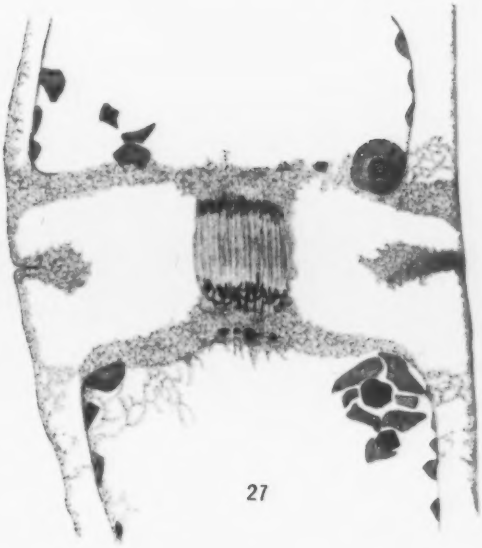

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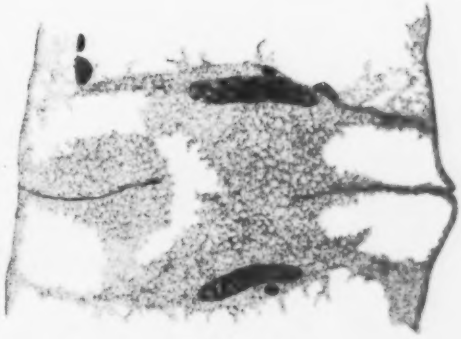

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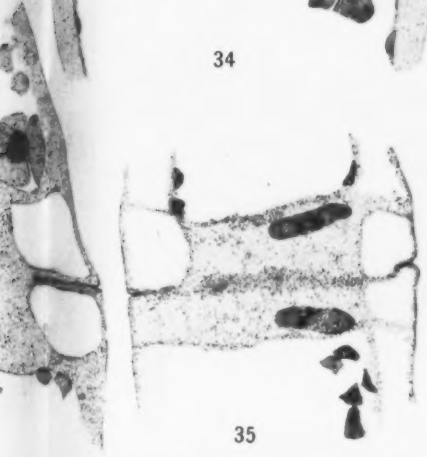

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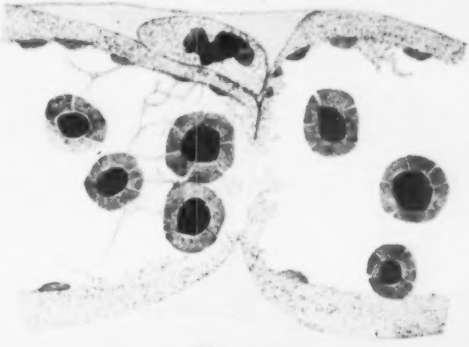

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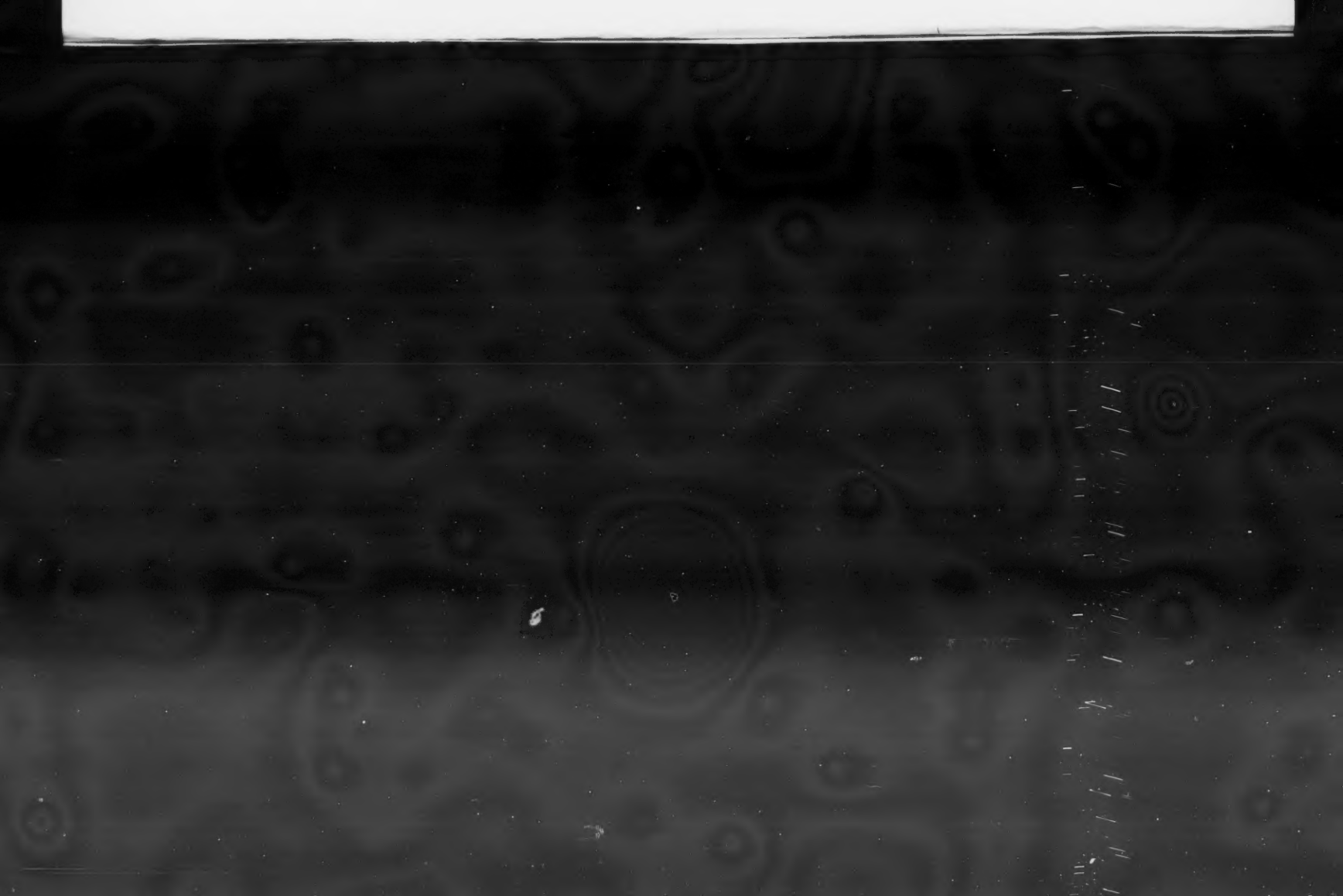
AN on CLOSTERIUM



THE GENUS EVERNIA AS REPRESENTED IN NORTH AND MIDDLE AMERICA

R. HEBER HOWE, JR.

(WITH PLATES XXIV AND XXV)

Genus: EVERNIA Ach. Lich. Univ. 84 et 441. 1810

The species of the genus, since 1753, have appeared under the following: *Lichen* L. (1793), *Lichenoides* Hoffm. (1790), *Lobaria* Hoffm. (1795), *Usnea* Hoffm. (1795), *Parmelia* Ach. (1810), *Borrera* Ach. (1810), *Physcia* DC. (1815), *Cornicularia* DC. (1815), *Ramalina* Chev. (1826), *Archevernia* Th. Fr. (1831), *Letharia* Th. Fr. (1831), *Phacopsis* Tul. (1852), *Chlorea* Nyl. (1859), *Rhylidocaulon* Nyl. (1859), *Alectoria* Mudd (1861), *Nylanderaria* Kuntze (1891); comparatively few of these, however, are generic synonyms.

DESCRIPTION: *Apothecia* subterminal, marginal or lateral; scutelliform, applanate or concave, sometimes convex and lacerate; marginate (thalloid dilations=*vulpina*); thalline exciple *rugose;* disk chestnut. *Asci* clavate, containing eight spores; paraphyses gelatino-filamentous. *Spores* monoblast, hyaline, ellipsoid. *Spermogones* immersed, black. *Sterigmata* branched, articulate. *Spermatia* acicular, incrassate near apices.

Thallus caespitose, subpendulous or pendulous, branched; cortex rugose, sometimes perforate, smooth, furfuraceous or isidioid, subterete (subradial), compressed (bifacial) or angulate; rhizinae rarely present; sulphur yellow, stramineous, virescent-stramineous, or cinereous; *medulla* cottonous, arachnoid, or somewhat coalescent. *Gonidia*, *Protococcus* (*Cystococcus humicola* Naeg.). *Soredia* normal. *Cephalodia* small, often warty, concolorous, sea-green or black, often gelatinous.

OBSERVATIONS: After all has been said, I can see no sufficient reason for separating the genus as given by TUCKERMAN. That the species here considered all have *cottonous* arachnoid medullas, whether more or less coalescent, cannot be questioned, and in none of the species does a true *chondroid*, axial cord exist. This slight variation in the condition of the medulla (one more or less of growth) does not in the least justify generic separation. It is true, as TUCKERMAN pointed out, that thalline differences must always constitute our criteria for generic distinction in this most difficult group of plants; yet if

thalline differences are recognized beyond a certain plausible degree, it is hardly exaggerating to say we shall have eventually nearly as many genera as species. In fact in the present genus this is now almost true. In true *Evernia prunastri*, the type of the genus, a bifacial structure of the laciniae is evident. This condition becomes obscure in the variety *thamnodes*, and in *vulpina* it is nearly radial. In *divaricata* the bifacial structure is about as in *thamnodes*, while in *Trulla* and true *furfuracea* it is markedly bifacial (*parmelioid*), but in the latter's varieties (apical portions) *ceratea* and *cladonia* the radial structure is again approached. If a careful study of the thalline structure of the species here considered is made, it will be seen that the pendulous, prostrate condition of growth typical of this genus tends to destroy a complete radial development. A portion of some of the branches of almost every individual plant shows a bifacial structure, owing to the gonidia seeking the uppermost or light-exposed side. In the truly pendulous *Usneas* and *Alectorias*, and wide branching, rigid, non-prostrate *Ramalinas*, and in the rigid cespitose species of the two former genera, the complete exposure develops a truly radial structure. In the present genus, it is not strange therefore that we find the luxuriant and more rigid examples of *vulpina* and the longest pendulous specimens of *divaricata* most nearly approaching the radial condition. In other words, so far as the sectional structure of the laciniae is concerned, *Evernia* holds an intermediate position between the strictly radial *Usneae* and *Alectoriae*, and the bifacial *Parmeliacei*.

The rare tropical lichen *Evernia Trulla* (Ach.) Mont. was set apart by NYLANDER in a unique genus, *Everniopsis*. I have been able to study but one specimen of this plant, kindly loaned me by the National Museum, and the scarcity of material thus precludes a sufficient study to settle satisfactorily the question of its classification in my own mind. There is no question that the plant morphologically is nearest to *furfuracea*, as TUCKERMAN pointed out, and its bifacial and membranaceous thallus can hardly be said to have a chondroid axis, in fact a compressed stuppeous condition is all that appears to me evident.

The striking similarity between the corniculate smooth *Evernia furfuracea* var. *ceratea* (Ach.) Nyl. from the highest alpine zone, and *Parmelia physodes* var. *vittata* Ach. is undebatable, and extends somewhat further than a mere superficial resemblance. In fact, the points of differentiation are hardly traceable, lying for the most part in the inflated laciniae, and ecanaliculate condition of the thallus. This striking similarity attracted the attention of NYLANDER and CROMBIE, and was perhaps the cause of the glossarial adjective "evernioid."[1] There is every reason to hold this genus in close proximity to *Parmelia*.[2] *Evernia* (*?Alectoria, Letharia*) *canariensis* (Ach.) Nyl. shows also

[1] NYLANDER, Flora **52**:445–446. 1869.

[2] *Parmelia Camtschadalis* var. *americana* (Mey. et Flot.) Nyl., except for its rhizinae, strongly resembles this variety, a canaliculate condition being here present.

its close relation to *Alectoria*, as *Evernia trulla* (Ach.) Mont. likewise suggests a *Cetrarian* relationship, through *Platysma everniellum* Nyl., etc. Dr. ZAHLBRUCKNER has placed *furfuracea* with the *Parmelias*, but has left *prunastri* with this genus. To me this seems inconsistent, as both are structurally bifacial,[3] though the former rarely shows a few rhizinae. He has also included *divaricata* under his *Letharia*, separating it thus generically from *prunastri*.

From the foregoing observations it is evident that this complex genus presents a transitional thalline condition, which though undeserving separation, as already pointed out, will be made more clear perhaps, if three sectional distinctions are indicated in our nomenclature. This was done in part by TH. FRIES in 1871.

Section: LETHARIA Th. Fr. Lich. Scand. 32. 1871

Thallus subradial, medulla cottonous, coalescent into axial strands

EVERNIA VULPINA (L.) Ach.

TYPE: Not indicated; the specimen on which LINNAEUS based his species is in the Dillenian herbarium, Botanic Gardens, Oxford, England, and according to CROMBIE and earlier writers is "*Physcia flavicans* (Sw.)" = *T[h]eloschistes chrysophthalmus* var. *flavicans* (Ach.) Tuck. All the pre-Linnaean botanists referred to the same Dillenian plate and specimen, and were followed by LINNAEUS. VILLARS in 1789, however, described diagnostically the true *Evernia* from Briançon, France, basing his species on HALLEY, who questioned his own reference to the Dillenian plate. SOWERBY, E. FRIES, and other authors previous to 1831 were aware of the Linnaean misconception. FRIES, however, followed ACHARIUS, as have all since, saluting the *Evernia* by the name *vulpina*. As the "Ulf-Mossa," however, according to NYLANDER, is a common plant in Scandinavia, and *flavicans* not only is not listed but is an austral species, it seems probable that LINNAEUS gave the name to the proper plant, and his reference to the *Teloschistes* was an error. WAINIO also states that in the Linnaean herbarium "78 *Lichen vulpinus* = *Evernia vulpina* Ach."[4] The substrate given for *vulpina* by LINNAEUS is certainly more characteristic of the *Evernia* than of *flavicans*, i.e., "tectis, ligneis, muris." The name *vulpina* has stood now for nearly two centuries, and on account of the Linnaean error it would seem inadvisable to drop it for *aurata* of VILLARS,[5]

[3] "*Facie dissimilis*," HUE, Nouv. Arch. Hist. Nat. **8**:(4) 119. 1899; "dorsiventral," ZAHLBRUCKNER, Nat. Pflanz. 217. 1907.

[4] Meddel. Soc. pro Fauna et Flora fennica **14**:10. 1886.

[5] Professor MIRANDE, Université de Grenoble in litt. states that VILLARS' type is not now in the remains of his herbarium in the Museum of the Ville de Grenoble; see NYLANDER, Bull. Bot. Soc. France **10**:954. 1863.

the next available name; the type of which, according to NYLANDER, was in existence in 1863; according to Professor MIRANDE, under date of February 8, 1910, is not now to be found at Grenoble.

TYPE LOCALITY: "Europae."

ORIGINAL DESCRIPTION: "filamentosus ramosissimus erectus fastigiatus inaequali-angulosus."

FIGURE: SCHNEIDER, Guide to Lich., 2 ed. *pl.* 4. 1904.

SYNONYMY: *Lichen vulpinus* Linn. Spec. Pl. 2:1155. 1753; *Evernia vulpina* Ach. Lich. Univ. 443. 1810.

DIAGNOSIS: *Thallus* loosely caespitose, subterete, rugose, *sulphur-yellow*.

DESCRIPTION: typical. *Thallus* loosely caespitose, subterete to compressed (rarely pendulous), rigid; cortex rugose-lacunose, rarely perforate, sometimes proximally expanded and glabrous; virescent to sulphur-yellow; *primary branches* coarse, dichotomous, divaricate (max. length 15 cm.); *secondary branches* dichotomous, divaricate and attenuate. *Apothecia* subterminal, ample (max. diameter 2.6 cm.), appendiculate, thalline exciple rugose and expanding, disk chestnut, emarginate and ciliate. *Spores* 5–8.5 $\times$4.5–5.5 μ.

CONTINGENT PHASES: (*a*) thallus spotted with minute black dots (spermogones), finally largely blackening; (*b*) reduced, sterile and virescent; (*c*) yellow sorediate (*E. v.* γ *incompta* Ach. Lich. Univ. 444. 1810).

SUBSTRATA: Trees, fences, and occasionally on rocks (limestone).

GEOGRAPHICAL DISTRIBUTION: Common in the lower Boreal zone, reaching rarely the Transition. The species extends from the mountains of Lower California, 8500 ft. (*Hasse*), and Mexico, Orizaba Mt., 9000 ft. (*Stone*), northward to British Columbia (*Macoun*, *Herden*) and Alberta (*Macoun* and others). It occurs up to 10,000 ft. in the Rocky Mountains. Though not included in Miss G. E. COOLEY'S list of "Plants collected in Alaska and Nanaimo, B.C.," etc., nor in Miss CUMMINGS' "The lichens of Alaska," though she determined Miss COOLEY'S plants, yet in the Herbarium of the New York Botanic Gardens there are two sterile examples labelled *vulpina* in Miss CUMMINGS' handwriting, on a "Flora of Alaska" label "collected by Miss GRACE E. COOLEY." Although Miss COOLEY did not include the species in her list at all (from either Alaska or B.C.), yet it is most probable that the above specimens came from the latter place. Eastward this plant extends to Montana (*Rydberg*, *Vreeland*, *Williams*), Wyoming (*Willey*), Black Hills, South Dakota (*Hayden*), Nebraska (*Fink*), and Grant Co., Nebraska (*Rydberg*), from where I have seen it fertile. It is reported also from Wisconsin or

Minnesota (*Parry*) by Professor FINK.[6] It is rarely found fruited, however, near the geographical and altitudinal limits of its range.

OBSERVATIONS: This species owing to its vivid color is the most conspicuous of the genus. Though a new generic name (*Chlorea*) was proposed by NYLANDER for this and a few other species, and earlier a title *Letharia* (see WAINIO) by Th. FRIES (later again *Nylanderaria* Kuntze), as before stated there is no good reason for this distinction. A study of the plant shows intergrades approaching *prunastri*, through its variety, in thalline structure (and color), and it is quite evident that morphologically this species differs from *prunastri* less than *furfuracea*, with which *prunastri* has stood since 1825. The robust plant growing in the regions of heavy rainfall in California, Washington, and Oregon (set apart as var. *californica* by NYLANDER, though named already by NUTTALL[7] *columbiana* in 1834, if not by ACHARIUS *xantholina* in 1810), is not in the author's opinion worthy of varietal rank.

Section: ARCHEVERNIA Th. Fr. Lich. Scand. 29. 1871

Thallus bifacial to subbifacial, medulla cottonous

EVERNIA PRUNASTRI (L.) Ach.

TYPE: Not indicated; one of the specimens on which LINNAEUS based his species is in the Dillenian herbarium, Botanic Gardens, Oxford, England, and according to CROMBIE is "sterile." According to WAINIO "39 *Lichen prunastri=Evernia prunastri* Ach." as represented in the Linnaean herbarium.

TYPE LOCALITY: "Europae."

ORIGINAL DESCRIPTION: "foliaceus erectiusculus lacunosus: subtus tomentosus albus." Linn. Spec. Pl. **2**:1147. 1753.

FIGURE: [DILL., Hist. Musc. *pl. 21. f. 54=E. p.* var. *gracilis* Ach.; *55a=E. prunastri* (L.) (*soredifera*); *c* and *d=E. prunastri*, Ach.; *h=E. p.* f. *retusa* Ach. fide CROMBIE].[8]

SYNONYMY: *Lichen prunastri* Linn. *ibid.*; *Evernia prunastri* Ach. Lich. Univ. 442. 1810.

DIAGNOSIS: *Thallus caespitose* or subpendulous, *compressed* (bifacial), *rough*, *sorediate*, virescenti-stramineous.

DESCRIPTION: typical. *Thallus* loosely caespitose, subpendulous or pendulous, mollitinous, compressed, at length expanded, channeled, and paler below; *cortex* rugose-lacunose, more or less sorediate, stramineous to virescent; *primary branches* coarse,

[6] It is recorded from Maine (ECKFELDT, J. W., Flora Mt. Desert, Me., 252. 1894), but the record is very doubtful and needs verification. The record probably refers to the var. *thamnodes*.

[7] Jour. Acad. Nat. Sci. Phila. **7**:59. 1834.

[8] Pre-Linnaean references in brackets.

dichotomous, divaricate (max. length 12 cm.); *secondary branches* dichotomous, divaricate, furcate. *Apothecia* lateral, subpedicellate (max. diameter 6 mm.), disk chestnut, emarginate. *Spores* 5–7 $\times 3 \cdot 5$–$4 \cdot 5$ μ.

CONTINGENT PHASES: (*a*) more or less completely sorediate (*E. p. sorediferа* Ach. Lich. Univ. 443. 1810).

SUBSTRATA: Trees, dead wood, fences, roofs, and occasionally on rocks.

GEOGRAPHICAL DISTRIBUTION: This species is confined in North America to the Pacific coast. I have examined specimens from the San Gabriel Mts., Cal., northward to British Columbia. Its variety is the plant found throughout the rest of our area.

OBSERVATIONS: This lichen with its variety shows a common tendency (see *Usnea*) to vary from virescent on the Atlantic coast to stramineous on the Pacific. Specimens from the southwest have an inclination to expand their laciniae and to become channeled below, suggesting *furfuracea*. The apices are also more truncate and furcate; in fact the plants are comparable with the temperate European specimens which represent true *prunastri;* but both in Europe and throughout our area intergradation is shown, diverging types of laciniae occurring rarely in a single plant. Specimens from east of the Rocky Mountains and from Alaska are of the linear type, and were referred by WILLEY to *E. thamnodes* Nyl.[9] To settle upon the rightful name for this linear plant is most perplexing. It appears, however, as follows: The oldest traceable name that has been used is *arenaria* Retz., but the type of *Lichen arenarius* Retz.[10] has been kindly sent me by Professor OTTO R. HOLMBERG of Lund, and proves to be *Evernia divaricata* (L.) Ach. as cited by ACHARIUS, and not as by FRIES and NYLANDER as a variety under *E. prunastri*. The next possible cognomen used was given by ACHARIUS γ *gracilis* (*l.c.* 442), with the locality "Sveciae." In his herbarium, however, WAINIO[11] cites two specimens, one from "Helvetia" and one from "Kamtschatka." The former he says has "laciniis laevissimis" and seems a young form of *prunastri*, to which, he writes, ACHARIUS' second description (*Obs.*) without doubt refers. The latter specimen he says intermixed with it is *E. mesomorpha* Nyl. In the Acharian herbarium today (*fide* ELFVING) only the Kamtschatka specimens exist. Seeing therefore that ACHARIUS in his original description used the words "laciniis laevissimis"; that the Swedish plant has not been found in the herbarium; and that the one specimen, apparently lost, was "laevissimis," a character in no way fitting our variety, we must pass on to the next available name. This we find was given by FLOTOW (*l.c.*) in a very

[9] FLOTOW, Lich. Schles. no. 54 *c.* 1829; and KOERBER, Syst. Lich. Germ. 42. 1855.

[10] Fl. Scand. Ed. 2. 292. 1795.

[11] Meddel. Soc. Faun. et Fl. **8**:117. 1881.

rare text accompanying his exsiccati which I have been unable to see, but is later cited by KOERBER as a trinomial: *Evernia prunastri β thamnodes* Flot. KOERBER curiously enough makes it synonymous with *Physcia divaricata β arenaria* Schaerer, showing the cycle of error caused by the RETZIUS specimen. HUE has used this name for our plant in the combination *Letharia thamnodes* (*l.c.* 58). NYLANDER described *E. mesomorpha* (Lich. Scand. 74. 1861), a name now generally considered synonymous; and again in the last year G. K. MERRILL distributed the plant as *Evernia prunastri* form *mollis* Merrill (Lich. exs. no. 51). It is very unlikely that the var. *vulgaris* Koerber (*l.c.*) is a synonym of *thamnodes*, but it seems quite plain that *gracilis* Ach. and *stictoceras* Sowerby are synonymous and do not refer to this plant; and it is not improbable that *E. mesomorpha* f. *esorediosa* Nyl. (Lich. Japan. 25. 1890) belongs with these.

EVERNIA PRUNASTRI var. THAMNODES Flot.

TYPE: No. 54*c* FLOTOW, Lich. vorzüglich in Schlesien 1:1829.

TYPE LOCALITY: "Sveciae."

ORIGINAL DESCRIPTION: "Thallus utrinque concolor laciniis longioribus angustioribus implexis verrucoso-furfuraceis" (KOERBER); and "Fruticulosa, undique corticata, similaris verrucoso-furfuracea" (WENDT, Thermen zu Warmbrunn, 94. 1840).

FIGURE: HOWE, Common and Conspicuous Lich. N.E. pt. 1. 24. 1906. FINK, Lich. Minn. Cont. U.S. Nat. Herb. **14**: *pl. 39.* 1910.

SYNONYMY: *Evernia prunastri β thamnodes* Flot., KOERBER, Syst. Lich. Germ. 42. 1855.

DIAGNOSIS: *Thallus* prostrate, *subterete* (subradial), rough, *virescent.*

DESCRIPTION: typical. *Thallus* caespitose, prostrate, subterete; *cortex* rugose, rarely sorediate, virescent; apices of branches *acuminate;* otherwise as in last.

SUBSTRATA: Same as last.

GEOGRAPHICAL DISTRIBUTION: Found throughout the Transition and lower Boreal zone. It is reported from Newfoundland (*Eckfeldt*) and from Manitoba (*Macoun*) and Vermillion Lake, Ontario (*Arthur*, etc.). It becomes rare, however, in northern Maine and Oregon, and is not reported from Labrador. RICHARDSON collected it, however, in Arctic America, Ft. Franklin, Great Bear Lake (1836), and I have examined several fertile specimens collected on *Betula* at Dawson, Yukon, Canada, by Mr. R. S. WILLIAMS early in the spring of 1899. HUE records *E. thamnodes* (Flot.) Nyl. from Port Clarence, Alaska, the White Mts., and "Otawa." Southward it extends to the border of the upper Austral zone. I have seen specimens from New York (*Harris, Blake*), Fayette, Iowa, Minnesota, Ohio, and Nebraska (*Fink*). SWARTZ recorded it (?) from the West Indies (1791).

It is this variety that has been commonly distributed as *Evernia prunastri* in most of the North American exsiccati.

EVERNIA DIVARICATA (L.) Ach.

TYPE: Not indicated; the specimen on which LINNAEUS based his species is in the Dillenian herbarium, Botanic Gardens, Oxford, England, and "is represented . . . . by only two or three sterile laciniae" according to CROMBIE. According to WAINIO, "*Lichen divaricatus*=*Evernia divaricata* Ach.," as represented in the Linnaean herbarium.

TYPE LOCALITY: "Helvetiae."

ORIGINAL DESCRIPTION: "filamentosus pendulus angulatus articulatus intus tomentosus, ramis divaricatis, peltis orbiculatis sessilibus." Linn. Syst. Nat. 713. 1767.

FIGURE: [DILL., Hist. Musc. *pl. 12. f. 5.* 1741]. HOFFM., Descript. et adnum. Lich. *pl. 67. f. 1, 2, 3.* 1801.

SYNONYMY: *Lichen divaricatus* Linn. Syst. Nat. *ibid.*; *Evernia divaricata* Ach. Lich. Univ. 441. 1810.

DIAGNOSIS: *Thallus* pendulous, *flaccid, compressed* (subbifacial), glabrous, stramineous.

DESCRIPTION: typical. *Thallus* pendulous, flaccid, subterete, compressed or angulate; cortex glabrous rugose and annularly ruptured, exposing cottonous medulla, stramineous; *primary branches* divaricate, dichotomous, sometimes echinate (max. length 35 cm.); *secondary branches* dichotomous, apices acuminate and darkening. *Apothecia* uncommon, lateral, small (max. diameter 2–6 cm.), marginate, thalline exciple rugose, disk chestnut, margins finally crenulate. *Spores* 5–10×3.5–6 μ.

CONTINGENT PHASES: unobserved.

SUBSTRATA: On coniferous trees.

GEOGRAPHICAL DISTRIBUTION: Occurs rarely in the Boreal zone. It has been reported from the following localities in the Rocky Mountains: California (*Hall*), Colorado (*Brandegee*), Bamff (*Macoun*), Mt. For-get-me-not, Elbow River (*Macoun*), British Columbia (*Macoun*). I have seen specimens from Divide Mt., 8000 ft., Montana (*Williams*), and Alpine, Colorado. The specimen in the U.S. Nat. Herbarium from Colorado, collected by Professor G. VASEY (referred to by TUCKERMAN), is unquestionably *Usnea cavernosa* Tuck. I have seen no fertile specimens from our area.

OBSERVATIONS: This plant is so rare in North American collections that its exact range is little known. It is undoubtedly a Boreal species, and may be looked for throughout the Rocky Mountains above 7000 ft. Its extreme flaccidity, and more or less compressed thallus, distinguishes it from *Usnea*,

which it in some degree suggests, on account of its annularly scarred thallus. The soft, cottonous, compressed medulla is at once seen, however, to be very unlike the terete, chondroid cord of *Usnea*. Like *thamnodes*, this species and *vulpina* have what has been considered a radial thallus. The structure cannot be said, however, to be strictly radial, and intergrades both individually and in species relation.

Evernia furfuracea (L.) Mann.

Type: Not indicated; the specimen on which Linnaeus based his species is not in the Dillenian herbarium, Botanic Gardens, Oxford, England, "but two specimens which are there are smaller and sterile, though sufficiently typical" according to Crombie. According to Wainio "33 *Lichen furfuraceus=Evernia furfuracea* Mann.," as represented in the Linnaean herbarium.

Typical locality: "Europae."

Original description: "foliaceus decumbens furfuraceus: laciniis acutis: subtus lacunosis atris," Linn. Spec. Pl. **2**:1146. 1753.

Figure: [Dill., Hist. Musc. *pl. 21. f. 52.* 1741]; Hoffm., Descript. et adnum. Lich. *pl. 9. f. 2.* 1790.

Synonymy: *Lichen furfuraceus* Linn. *ibid.*; *Evernia furfuracea* Mann. Lich. in Boh. obs. despos. suc. des. 105. 1825.

Diagnosis: *Thallus* caespitose or subpendulous, compressed (bifacial) and *channeled, furfuraceous-isidioid, cinereous.*

Description: typical. *Thallus* prostrate, caespitose, or subpendulous, compressed, pliant, channeled below; cortex above furfuraceous to isidioid, below lacunose; above cinereous, below white, at length blackening; *primary branches* dichotomous, subpinnate (max. length 15 cm.); *secondary branches* much divided, apices furcate or tripartate. *Apothecia* marginal, subpedicellate, ample (max. diameter 1.7 cm.), disk chestnut. *Spores* 5.5–8× 3.5–5 μ.

Contingent phases: reduced, sterile (boreal swamps in Transition regions).

Substrata: Coniferous and deciduous trees.

Geographical distribution: Found throughout the Transition zone as far south as Bergen, New Jersey (*Eckfeldt*); Albany, New York; Pike Co., Penn.; Ohio (*Bogue*); Walker Mts., Smyth Co., Virginia; Grandfather (*Cummings*) and Crowden Mts., N.C.; Florida (*Calkins*); Tennessee (*Moore*); and Orizaba Mt., Mexico (*Stone*). Westward it extends to Minnesota (*Fink*). It reaches northward only to the lower limits of the Boreal zone, practically all alpine (over 3000 ft.) examples being referable to the following variety.

OBSERVATIONS: This species is found to intergrade with its variety where they meet on the mountain sides of the southern peaks; intermediate and atypical specimens having been examined from Grandfather Mt., S.C.; at Coahuita, and on Orizaba Mt., Mexico. Fertile examples of the species are rare, and the apothecia always smaller than in the variety.

EVERNIA FURFURACEA var. CERATEA (Ach.) Nyl.

TYPE: Not indicated; but the specimens on which the species was based are in the Acharian herbarium, Universitets Botaniska Institution, Helsingfors. These specimens have been kindly sent me for examination by Dr. FRED. ELFVING. The two labelled "var. *ceratea*" are typical fruited specimens, showing the characteristic "corniculato ramosis," and nearly smooth thallus. The specimens of the varieties β *nuda* and δ *scobisina* (see figure) were formerly indicated on the mounts by * and ‡, but these marks were either erased by ACHARIUS or some later worker, so that the exact identification of the (sterile) specimens referred to is in doubt. In any event, the specimens are referable to the species *furfuracea* rather than to the corniculate variety. The variety γ *scobisina* is indistinguishable from the species, being only a name for a more isidiod contingent phase, while *nuda* was not recognized in the *Methodus* (1803) as were the other varieties, but was first described in 1810. *Nuda* represents a contingent phase of *furfuracea* unworthy of recognition, transitional at best, though curiously enough the only one retained by *Acharius* in the *Synopsis* of 1814.

TYPE LOCALITY: Not indicated, but the above specimens are labelled "Svecia."

ORIGINAL DESCRIPTION: "thalli laciniis angustioribus suberectus corniculato-ramosis acuminatis supra incanis glabris nudiusculis."

FIGURE: none.

SYNONYMY: *Parmelia furfuracea* β *ceratea* Ach. Method. Lich. 2:255. 1803; *Evernia furfuracea* var. *ceratea* (Ach.) Nyl. Lich. Scand. 73. 1861.

DIAGNOSIS: Similar to last, *glabrous*, branches *subcylindrical* near apices, apothecia *ample*.

DESCRIPTION: typical; similar to last. *Thallus* more *gross;* cortex glabrous above, sometimes verrucoso-papillate, rugose or pitted, black spermogones frequent, branches distally subcylindrical, often linear. *Apothecia* common, at length crowded, ample (max. diameter 1.8 cm.). *Spores* as in last.

CONTINGENT PHASES: reduced branches with apices alike on both sides, entangled (*E. furfuracea* var. *Cladonia* Tuck.).

GEOGRAPHICAL DISTRIBUTION: Confined to alpine regions of the Boreal zone at altitudes of over 3000 ft. It occurs on the Appalachian range: in New Hampshire on the White Mts.; in Vermont I have seen it only from Mt.

Ascutney; in New York it is reported from Panther Mt., Catskills (*Harris*), and Mt. Whiteface, Adirondacks (*Peck*); and some of the material distributed from Grandfather Mt., N.C., by Miss CUMMINGS (Decades N. Amer. Lich. No. 2) is referable here. It undoubtedly occurs on Mt. Katadin, Me., and I have seen specimens from Ontario, Canada. The plants from the eastern United States are nearly always sterile or show rarely minute apothecia, entirely smooth and more "thyrsoid-entangled," and may possibly be worth recognition under the var. *Cladonia*[12] of TUCKERMAN, though they are in reality probably only reduced conditions of the more alpine fertile plant. In the Rocky Mountains I have seen specimens from alpine regions reaching 10,200 feet, extending from Colorado (Lake Moraine, Pikes Peak; Pagosa Peak, Veta Pass), New Mexico (Socorro Co., Mt. Gray), Arizona, Texas (*Parry*), southern California to Mexico (Coahuila, Monterey, San Luis Potosi,[13] Mt. Orizaba).

OBSERVATIONS: This plant in its fruited condition, as already noted, strongly suggests morphologically the var. *vittata* Ach. of *Parmelia physodes*. It is also interesting to note that TUCKERMAN[14] first considered the examples referable to his *Cladonia* nearest to ACHARIUS' *ceratea*.

Section: EUEVERNIA sect. nova.

Thallus bifacial, medulla stuppeous, compressed, non-chondroid

EVERNIA TRULLA (Ach.) Mont.

TYPE: Is in the Acharian herbarium, Universitets Botaniska Institution, Helsingfors, according to Professor FRED. ELFVING in litt. May 8, 1910.

TYPE LOCALITY: Peru, South America.

ORIGINAL DESCRIPTION: "thallo membranaceo subcaespitosa albido-pallescenti utrique nudo glabro subtus canaliculato, laciniis linearibus dichotomis; scutellis marginalibus cyathiformibus rufo-fuscis, margine subtusque crenulato-rugosis."

FIGURE: Method. Lich. *pl. 4. f. 6.* 1803.

SYNONYMY: *Parmelia trulla* Ach. Meth. Lich. 256. 1803; *Evernia trulla* Mont. C. Gay, Fl. Chil. **8**:74. 1852.

DIAGNOSIS: *Thallus* caespitose decumbent, *compressed* (bifacial), glabrous, canaliculate, pale virescent.

DESCRIPTION: typical. *Thallus* caespitose, decumbent, compressed, canaliculate; cortex glabrous, glauco-virescent, darkening

[12] Synop. Lich. N. E., etc. 12. 1848. Type: No. 56, Fasc. 3, 4, Lich. Amer. Sept. exsiccati, 1854. Type locality: "Montium Alborum."

[13] Material from here showed a few rhizinae.

[14] Further enum. N. E. Lich. Bost. Jour. Nat. Hist. **3**:300. 1840.

beneath; *branches* dichotomous. *Apothecia* lateral, subcyathiform, exciple rugose, disk chestnut-brown. *Spores* 11–16×7–9 μ.

SUBSTRATA: On the ground.

GEOGRAPHICAL DISTRIBUTION: Mexico.

OBSERVATIONS: This rare North American plant has been only recorded from Mexico. It seems in every way logical that this species should therefore stand last of the *Evernias*, and next before the *Parmeliaceae* in our taxonomy. This relation has been assigned this genus by ZAHLBRUCKNER, with the removal of *Cetraria* into the *Parmeliaceae*, where it occupies a position preceding *Evernia*.

HUE records *Evernia intensa* Nyl.[15] from Mexico. The species is apparently a chemical one, of which there is probably but little material. I have been unable to see the plant.

In closing this paper it is a great satisfaction to learn that at the Congress at Brussels *Linnaeus Species Plantarum* (1753) has been approved as the starting point for lichenological nomenclature. The labor involved here and in my *Usnea* paper in settling the priority of names is therefore not in vain.

For the opportunity to complete this paper I am indebted largely to Dr. N. L. BRITTON, who extended me during the past year a Garden Research scholarship, which was unfortunately cut short by ill health. To many others connected with the New York Botanic Gardens, to Dr. G. C. ALLEN, Dr. L. W. RIDDLE, Dr. FRED. ELFVING, Prof. BRUCE FINK, Dr. H. E. HASSE, DR. R. W. DRECHSLER, Mr. L. K. LUNT, and numerous other friends I am also most grateful.

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EXPLANATION OF PLATES XXIV AND XXV

FIG. 1.—DILLENIUS plate of *Evernia prunastri* (L.) Ach. (Lichenoides).

FIG. 2.—DILLENIUS plate of *Evernia divaricata* (L.) Ach. (Lichenoides).

FIG. 3.—RETZIUS type of *Lichen arenarius*=*Evernia divaricata*.

FIG. 4.—DILLENIUS plate of *Evernia furfuracea* (L.) Mann. (Lichenoides).

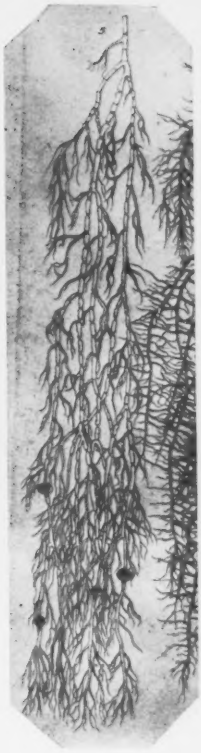
FIG. 5.—*Evernia Trulla* (Ach.) Mont. from a specimen in the U.S. Nat. Herb.

FIG. 6.—Acharian types of *Evernia furfuracea* and varieties (Borrera).

FIG 7.—*Evernia furfuracea* var. *ceratea* (Ach.) Nyl. collected in Colorado by L. K. LUNT.

[15] Flora **30**:546. 1872; and Bull. Soc. Linn. Norm. **6**:269. 1872.

1



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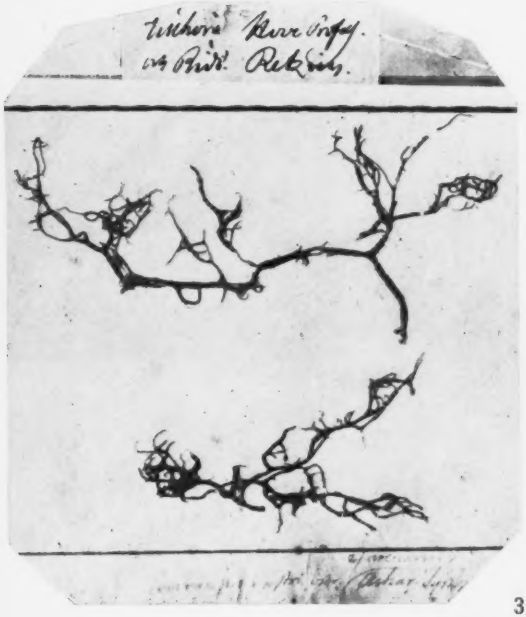

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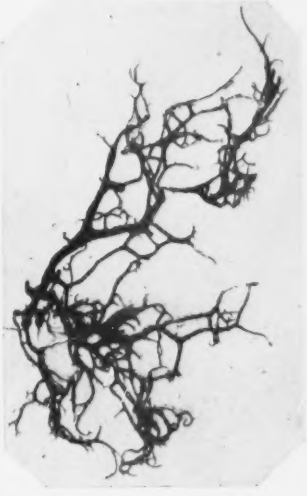
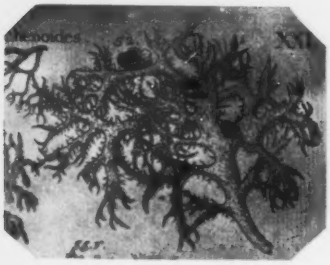


HOWE on EVERNIA



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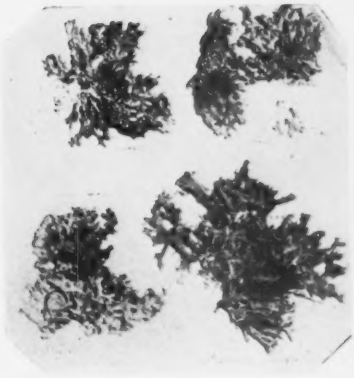

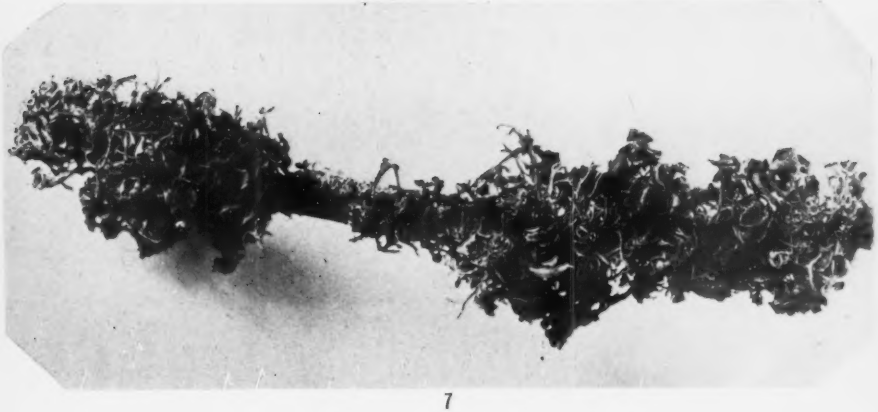

7

HOWE on EVERNIA

IMBEDDED SEXUAL CELLS IN THE POLYPODIACEAE

MARGARET C. FERGUSON

(WITH PLATES XXVI AND XXVII)

About five years ago an assistant in the botanical laboratories of Wellesley College, Miss ANN REBECCA TORRENCE, was asked to prepare a set of slides, illustrating the development of the sexual organs in the ferns, for general class use. In looking over the slides which she had marked as valueless, I found several preparations showing an unusual origin of the egg cells. These slides were put aside with the expectation of publishing a note in the near future.

In February 1910, Miss JEAN WINSLOW, a student in my advanced course in cytology and comparative morphology, was puzzled by certain structures which she found in several of her preparations. The material was fixed and prepared for study by the student herself under the direction of the laboratory assistant, Miss EMILY P. LOCKE. Upon examining her slides, I found that they contained numerous instances of imbedded antheridia.

The fern prothallia used for class purposes are grown by the gardener. He sows, in clay saucers containing especially prepared soil, the spores of *Pteris* and *Adiantum*, some dishes containing only spores of *Pteris* and others containing spores of *Adiantum*. In both instances the structures about to be described were taken from cultures marked "Pteris," probably *Pteris cristata;* but since the spores of other species of *Pteris* are sometimes sown, I cannot state definitely the exact species of *Pteris* which was studied.

When the imbedded antheridia were discovered, I looked up the slides showing the deep-seated origin of eggs in *Pteris*, and we had a very interesting class demonstration and discussion.

At that time I said to the class that similar phenomena had never before been seen in a leptosporangiate fern; at least, if seen, the observations had never been published. Within a week I

had made the drawings which appear in connection with this note, but was detained from writing at that time. A little later, in looking over some back numbers of the current botanical literature, I ran across Miss BLACK's paper describing imbedded antheridia in *Dryopteris* and *Nephrodium*.[1] It is interesting that with no knowledge of Miss BLACK's work I had come to practically the same conclusion as that outlined in her paper regarding the origin and development of these unusual structures. I publish herewith exactly the same figures, without change or addition, as were prepared before Miss BLACK's paper was read. No prothallium containing unusual sexual organs was studied that did not also show normal archegonia and antheridia in all stages of development.

There can be no question as to the presence of an imbedded antheridium in these leptosporangiate ferns very similar to that found in the eusporangiates. Compare figs. 11 and 12 of this paper with Campbell's figs. 125 *D*, 128 *B*, 152 *D*.[2] The origin of these antheridia is not so obvious. There is no doubt that, as described by Miss BLACK, they may have practically the same origin as archegonia, but they may present transitional stages between normal antheridia and archegonia. Fig. 1 shows a normal young antheridium in which the first wall formed was not sufficiently concave to reach the basal wall, as is ordinarily but not invariably the case. Had the initial cell failed to protrude before the laying down of this cross-wall, such a structure would have been formed as that shown in fig. 2. Here the second wall formed, the dome-shaped cell, is much more prolonged than is usual. But the protrusion of the outer cell may be much less (fig. 3), or there may be no arching at all (fig. 4), when we would have what is recognized as an early stage in the development of a normal archegonium. Miss BLACK finds that arching occurs only in later stages of development, but in *Pteris* there is undoubtedly a greater or less arching of the initial cell in many cases, as if it were unde-

[1] BLACK, CAROLINE A., The development of the embedded antheridium in *Dryopteris stipularis* (Wild.) Maxon and "*Nephrodium molle*." Bull. Torr. Bot. Club **36**: 557. 1909.

[2] CAMPBELL, D. H., Mosses and ferns. New York. 1905.

cided as to whether it should be an antheridium or an archegonium; but the arching in such cases is insufficient to make the resulting organ completely superficial.

The first wall laid down in the development of the imbedded antheridium is in the same plane as under normal conditions, but it may be deep-seated and little or not at all saucer-shaped (figs. 2, 3, 5). The second wall cuts out a central cell which may be very dome-shaped or may not be arched at all (figs. 2, 3, 5, 7, 8). The third wall follows in normal succession, cutting out the cover cell (figs. 5, 7, 8). The divisions occurring in the central cell of these antheridia in *Pteris* are somewhat different from those occurring in *Dryopteris* and *Nephrodium* as described by Miss BLACK. The first wall may sometimes be anticlinal and divide the cell into two equal cells, as is true under normal conditions (fig. 9*a*); but in the majority of cases observed the central cell of the entirely sunken antheridium was divided by two slightly oblique anticlinal walls into three cells lying in the same plane (figs. 7, 8).

Later stages in the development of the antheridium could not be traced beyond a question in the material at hand. But sooner or later a mass of cells occurs, from which the sperms are eventually produced. In order to meet the needs of the enlarged antheridium the one cover cell is replaced by a cell complex. As a rule, the mature imbedded antheridium is covered by a single layer of cells, but it may become two cells deep (fig. 10). In all cases observed, the imbedded antheridium is surrounded by a layer of cells much smaller than those which form the venter of an archegonium in the ferns, suggesting very strongly in their arrangement and appearance tapetal cells (figs. 10–12).

The size of the young, partially imbedded antheridia is practically the same as that of the normal antheridia, as is seen by a comparison of figs. 1 and 3, and figs. 5 and 6. But in later stages of development these unusual antheridia may become greatly enlarged. The more deeply sunken the antheridium the greater the size is apt to be at maturity. A normal, mature antheridium is shown in fig. 13. Compare this both as to position and size with the antheridia illustrated in figs. 11 and 12. Fig. 12 does not represent the largest antheridium observed. It was figured

rather to show that these organs not only may not protrude but that the cover cells may actually be depressed. Several antheridia much larger than this were observed. The sperm cells, while perfectly normal in appearance, are considerably larger than those developed under the usual conditions.

Imbedded antheridia were not found on the prothallia showing an unusual origin of the egg cells. In the case of the archegonia, the most frequent deviation from the normal gave two egg and two ventral canal cells lying in the plane of the longer axis of the archegonium (fig. 15). There is little doubt in this case that the more deeply imbedded egg and ventral canal cell were derived from the basal cell of the young archegonium. Ordinarily this cell contributes to the formation of the venter of the archegonium. In several instances the basal cell contained a beautiful, spherical mass of dense cytoplasm with a large nucleus, presenting the appearance of a large central cell before its division to form the ventral canal cell and the egg cell (fig. 14). The preparations studied showed egg cells that were unquestionably derived from other cells of the venter, but in these instances the sections were cut at such an angle as to render the figures unfavorable for reproduction.

There is no evidence that these deep-seated eggs or the imbedded antheridia were developed in response to dryness, as was the case in Miss BLACK'S material. The two prothallia containing each seven or eight abnormal antheridia and the three prothallia showing several deep-seated eggs occurred in cultures from which a large amount of material was put up, and no other prothallia showed any deviation from the normal. Of course the fact remains that these particular prothallia may have been in positions of especial exposure, but, considering the method of culturing the prothallia, this is not probable.

I shall not enter into a prolonged discussion of the significance of these structures, since this has been so recently and so ably done by Miss BLACK. I wish simply to emphasize the point which she makes regarding the bearing of these phenomena on the question of the determination of sex in monoecious prothallia, and on the problem of vegetative fusion as described by recent writers.

In this connection the condition represented in fig. 9*b* is very interesting. Here we have apparently the first three cells of an archegonium, in which the central cell has developed directly into what is to all appearances a sperm cell. This leads us to inquire at what point in the development of a prothallium the sexual nature of its cells is determined. Are we not too much accustomed in our thinking to combine the idea of sexuality with form and position and definite organs? It may be that maleness and femaleness have no necessary relation to form or position or sexual organs, but that sperms and eggs are developed in relation to the sexual act or process, not as a necessary expression of sexuality. Should this be found to be true, then many cases of so-called vegetative fusion may come to be considered simply as instances of early or premature fertilization. To determine the point in the development of monoecious prothallia at which certain cells become endowed with sexuality, and the characteristic which makes them male or female, is one of the interesting but difficult problems which await solution.

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EXPLANATION OF PLATES XXVI AND XXVII

Unusual conditions in the development of the antheridia and the archegonia in *Pteris*.

FIG. 1.—A young antheridium in which the first wall laid down is very slightly concave.

FIG. 2.—A young, partially imbedded antheridium; the first wall laid down is parallel with the basal wall and not at all concave, while the second wall is very greatly arched.

FIG. 3.—A similar stage to that shown in fig. 2, but the antheridium is more completely imbedded and the outer cell arches but slightly.

FIG. 4.—The three-celled stage either of a normal archegonium or of an imbedded antheridium.

FIG. 5.—A later stage in the development of a partially imbedded antheridium; the cover cell has been cut out in the usual manner.

FIG. 6.—A slightly later stage in the development of a normal antheridium.

FIGS. 7, 8.—Practically the same stage of partially or wholly imbedded antheridia as that shown in fig. 6; their position is entirely that of young archegonia.

FIG. 9*a*.—A later stage in the development of a partially imbedded antheridium; the first division of the central cell was evidently the same as under normal conditions.

FIG. 9*b*.—An early stage in the development of a normal archegonium or of an imbedded antheridium; in this case the central cell has apparently given rise directly to a sperm cell.

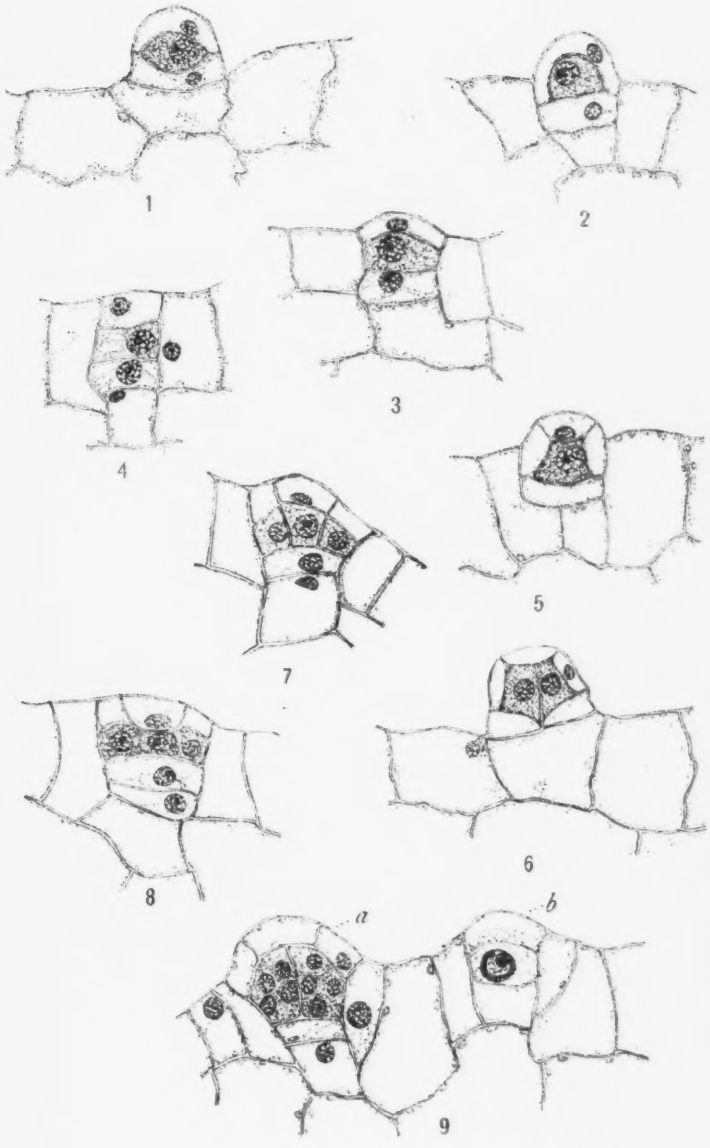
FIG. 10.—The sporogenous cells of an antheridium lying two layers of cells beneath the surface of the prothallium.

FIGS. 11, 12.—Two mature imbedded antheridia; both antheridia and sperms larger than those developed normally.

FIG. 13.—A mature, normal antheridium; note position and size as compared with those shown in figs. 11 and 12; these three antheridia were all taken from the same prothallium.

FIG. 14.—An archegonium normal in all respects except that the basal cell is greatly enlarged and contains either an egg or a protoplast which would later have divided to form a second egg and a second ventral canal cell.

FIG. 15.—An archegonium containing two egg and two ventral canal cells; the second egg and canal cells have evidently been derived from the basal cell.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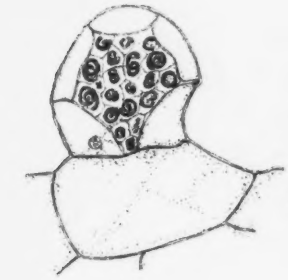

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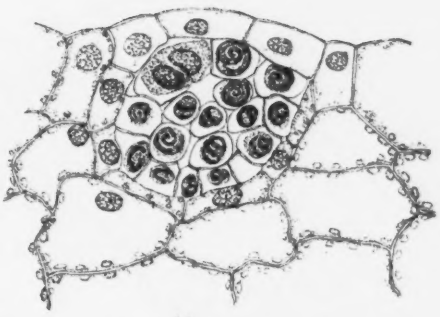

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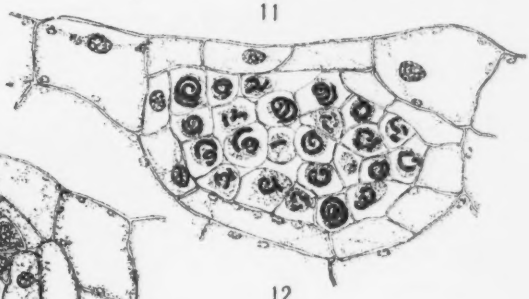

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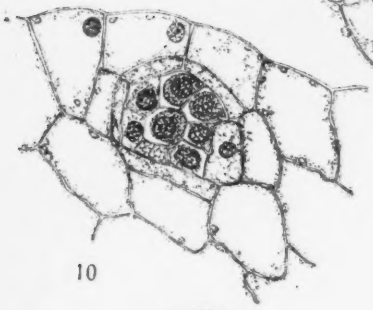

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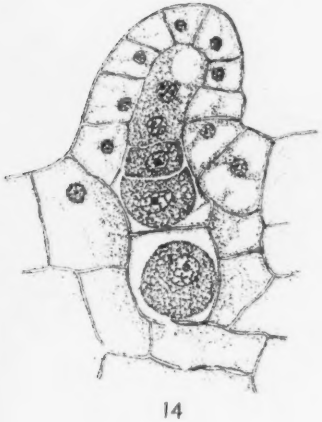

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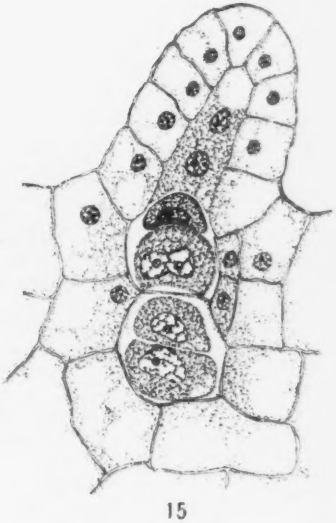

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AN AMERICAN LEPIDOSTROBUS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 144

JOHN M. COULTER AND W. J. G. LAND

(WITH PLATES XXVIII AND XXIX AND THREE FIGURES)

The remarkable uncovering of the structure of paleozoic strobili and seeds during the last decade, chiefly from sections of English and French material, has brought to the American morphologist a feeling of disappointment that the extensive American Coal-measure deposits have yielded these structures only as impressions or casts. Extended inquiry has failed to discover such petrified material in any of the collections, so that its occurrence is evidently quite unusual.

A short time since there came into our hands, through the courtesy of Dr. STUART WELLER, of the Department of Geology of this university, a specimen of *Lepidostrobus*, the strobilus of *Lepidodendron*, that was evidently petrified. It had been collected in 1900, in a coal pocket in Warren County, Iowa; and in January 1911 came into the possession of Professor JOHN L. TILTON, of Simpson College, Indianola, Iowa, who brought it to this university, and in whose collection a portion of the sectioned cone is to be found.

The specimen is not a complete strobilus, but a fragment from near the upper end, broken at an angle above, and squarely across below. As a consequence, if the strobilus was heterosporous, all evidence of the megasporangia had disappeared with the missing lower portion. The fragment is 6 cm. long and 5 cm. in diameter at base, and all the structures proved to be very well preserved except the axis (figs. 1 and 2), which had been almost completely destroyed and replaced by calcite and pyrites. The strobilus was a mature one, which had fallen and remained in the water or moist soil, for rootlets had penetrated between the sporophylls here and there, and the rootlets in turn had been attacked by a fungus. Nearly all of the sporangia are empty, only a few spores being occasionally in place, but masses of spores occur in many places between the sporophylls.

The general structure of *Lepidostrobus* is well known, but it seemed worth while to section this American specimen and to record the results. We have not attempted to refer it to any described species, as this would involve us in unfamiliar details. The only purpose is to describe briefly the structure of the first American Coal-measure strobilus to be sectioned, so far as we can discover.

The stalks of the crowded sporophylls stand approximately at right angles to the axis of the strobilus (fig. 2), and are triangular in cross-section, the keeled abaxial face fitting between two sporangia on the sporophylls below (fig. 4). This stalklike base of the sporophyll is about 20 mm. long, and broadens widely as it joins the lamina (fig. 5), whose plane is approximately at right angles to that of the stalk. The lamina is 20 mm. long, extending below the plane of the stalk in a broad triangular base and narrowing rapidly above into a long acuminate extension (fig. 8). The result is that each lamina overlaps several others above, the surface appearance of the strobilus resembling that of a roof covered with pointed tiles; and the broad, wavy, and notched base interlocks with the sporophylls below. The sporangia are thus very closely and heavily incased, and all the structures of the strobilus are fitted solidly together. A single and very simple vascular strand traverses the stalk of the sporophyll and continues into the lamina, consisting of a small central group of protoxylem elements (fig. 20), completely invested by a narrow zone of vessels of larger caliber, and this in turn by a broad zone of delicate tissue which abuts against the cortex.

In the narrow space between the distal end of the sporangium and the base of the lamina, the ligule appears as a small conical body arising from a shallow pit (fig. 16). This relationship of the ligule to the sporangium and the lamina of the sporophyll seems to be constant among the ligulate forms, the distance from the base of the sporophyll in this case being determined by the great radial extension of the sporangium. The cells of the sporophyll immediately below the pit of the ligule are much longer than the other cells, and radiate from the ligular pit. These radiating and elongated cells perhaps indicate that in the early stages of the sporophyll considerable photosynthetic work was done by the ligule.

The cells of the ligule itself are small and almost isodiametric; and its tip is invariably withered.

The most characteristic feature of *Lepidostrobus* is the radially elongated sporangium, which extends along the whole adaxial face of the stalk of the sporophyll. In our specimen the sporangium is 17 mm. long and 2.5–3 mm. broad, attached along the central axis of the stalk by a narrow connection, and bulging pouchlike beyond the sides of the stalk, until the latter broadens into winglike extensions near the lamina. Only in the distal region of the sporangium is there any evidence of a "subarchesporial pad," which appears in section as a broad and low dome of tissue (fig. 12); there is no evidence of any radiating sterile tracts within the sporangium.

The most notable feature of the sporangium, aside from its radial extension, is its dehiscence (fig. 6). A series of transverse sections indicates this very clearly (figs. 9–13), and also served as the basis of a restoration. The sporangium dehisces longitudinally along the median line for a little more than half its length from the base, and then the line of dehiscence forks and is represented in the distal half of the sporangium by two diverging lines, which leaves between them a large triangular flap of the sporangium wall. In most cases the structure of the outermost layer of sporangium wall is well preserved, consisting of the characteristic "prismatic palisade-like cells" (figs. 17 and 18). The wall, under pressure of the adjacent structures, is quite definitely angled (figs. 9 and 16), and at these angles the palisade-like cells are conspicuously elongated, and within the angles there are usually traces of the more delicate inner wall layers. No special mechanism of dehiscence was discovered, although it is reasonable to suppose that one exists in the case of this singular dichotomous or triradial dehiscence. Since the distal ends of the sporangia abut against the heavy interlocking bases of the laminae, it is altogether probable that the continuation of the median longitudinal dehiscence becomes mechanically impossible.

It is to be regretted that the basal part of the strobilus was not secured, so that the question of heterospory might have been answered. The spores observed are probably microspores, and their appearance is sufficiently indicated in fig. 19.

The fungus referred to above as accompanying rootlets that had penetrated among the sporophylls presents stages that seem worthy of record. The mycelium is abundant and wide branching, and suggests that of a phycomycete, since no cross walls are apparent except in a few cases, and these cases might be only such

FIG. 22

FIG. 21

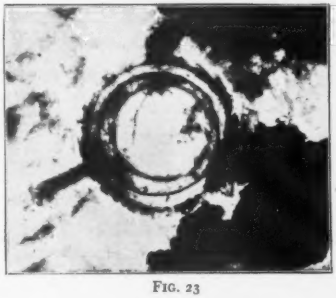

FIG. 23

FIGS. 21–23.—Fig. 21, Swollen end of hypha, suggesting a young oogonium; ×475; fig. 22, Hyphae showing two oogonia; ×475; fig. 23, Photomicrograph of fertilized egg (?) of fungus; ×141.

as appear among phycomycetes. In many instances the hyphae bear what are evidently zygotes; and such stages as that shown in fig. 21 suggest the development of a sex organ. The situation represented in figs. 22 and 23 furthermore suggests that the fungus had oogonia and antheridia. However, it is fully realized, as suggested by Dr. HASSELBRING, to whom our preparations were submitted, that such data may be insufficient to determine the fungus with definiteness; it may be an oomycete; or it may not even be

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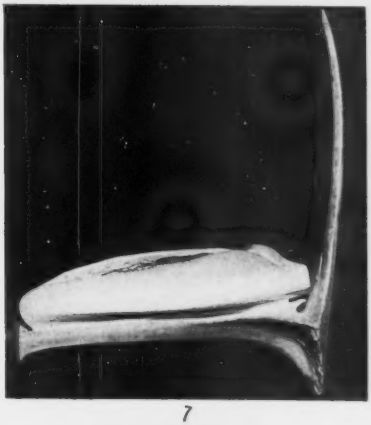

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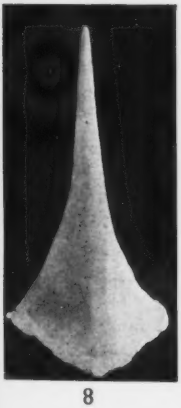

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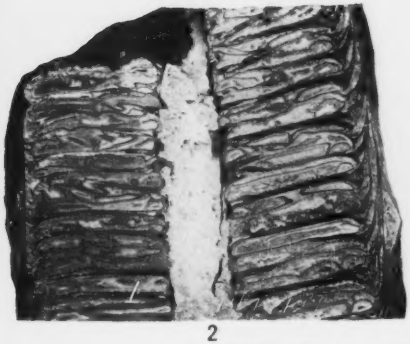

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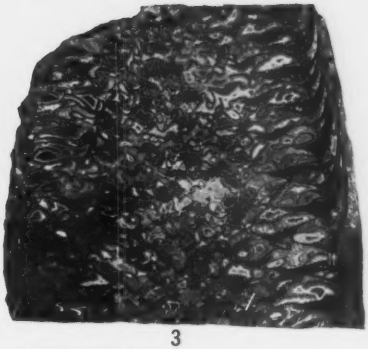

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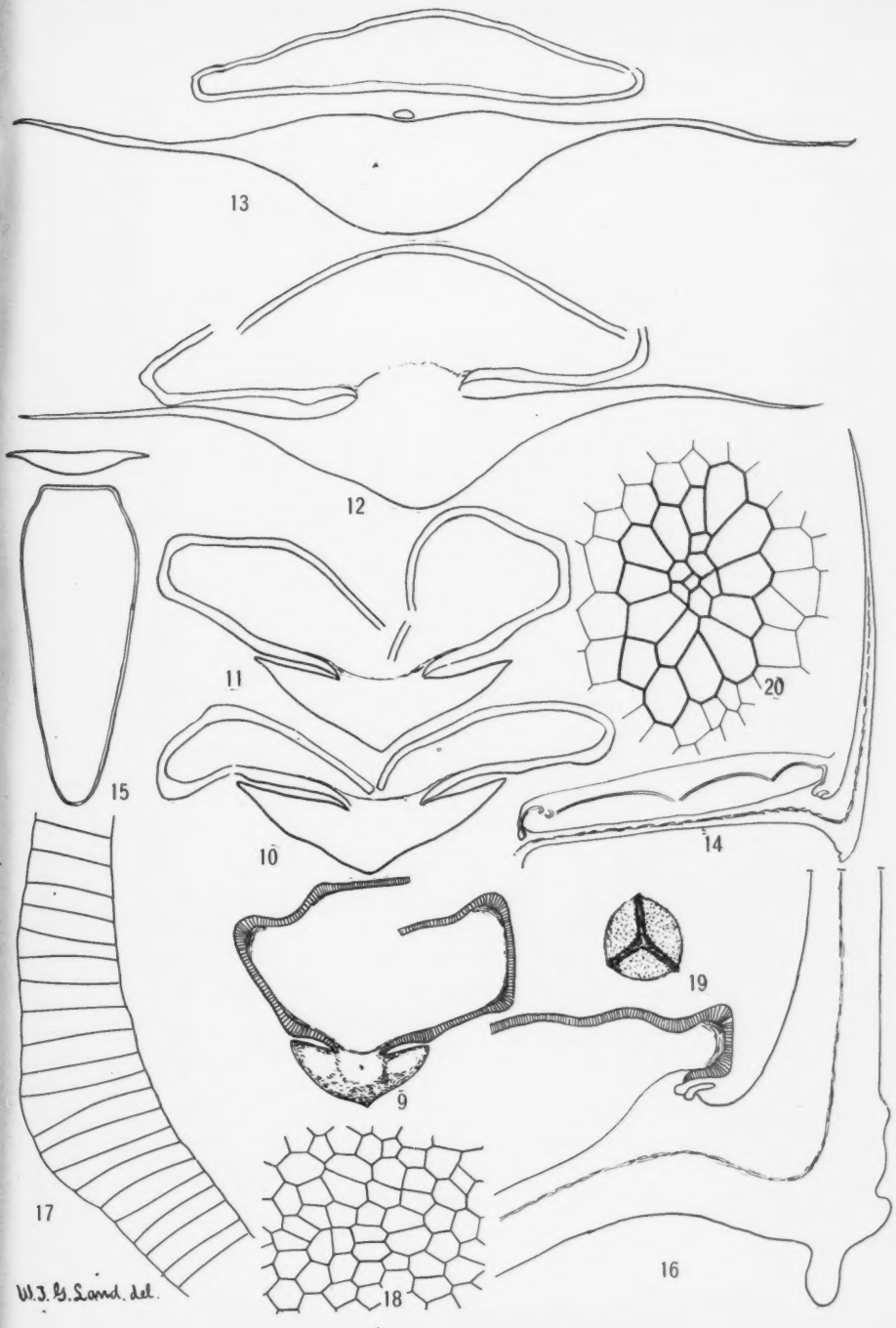
COULTER & LAND on LEPIDOSTROBUS



COULTER & LAND on LEPIDOSTROBUS

a phycomycete; but whatever it is, it became associated with rootlets that penetrated among the sporophylls of fallen strobili of *Lepidodendron*.

THE UNIVERSITY OF CHICAGO

EXPLANATION OF PLATES XXVIII AND XXIX

PLATE XXVIII

FIG. 1.—Transverse section of strobilus; ×1.

FIG. 2.—Median longitudinal section of strobilus; ×1.

FIG. 3.—Tangential section of strobilus; ×1.

FIG. 4.—Transverse section of sporophyll 10 mm. from axis; ×12.5.

FIG. 5.—Abaxial view of sporophyll, from a reconstruction in plaster; ×2.5.

FIG. 6.—Abaxial view, showing dehiscence of sporangium; ×2.5.

FIG. 7.—Lateral view of sporophyll, showing relation of sporangium and ligule; ×2.5.

FIG. 8.—Abaxial view of lamina of sporophyll; ×2.5.

PLATE XXIX

FIG. 9.—Transverse section of sporophyll 1 mm. from axis; ×12.5.

FIG. 10.—Transverse section of sporophyll 6 mm. from axis; ×12.5.

FIG. 11.—Transverse section of sporophyll, showing triradiate dehiscence; ×12.5.

FIG. 12.—Transverse section of sporophyll near distal end; ×12.5.

FIG. 13.—Transverse section through sporophyll, ligule, and free distal end of sporangium; ×12.5.

FIG. 14.—Median longitudinal section through a sporophyll from basal egion of strobilus, showing ligule and path of vascular strand; ×2.25.

FIG. 15.—Median longitudinal section of sporangium parallel with the axis of the sporophyll; ×2.25.

FIG. 16.—Median longitudinal section through ligule, showing general relations of parts; ×58.

FIG. 17.—Section through sporangium wall, showing the palisade-like cells; ×229.

FIG. 18.—Section of sporangium wall parallel with its surface; ×229.

FIG. 19.—Microspore (?); ×475.

FIG. 20.—Detail of xylem of vascular bundle of stalk of sporophyll, showing central protoxylem; ×475.

SUGGESTIONS CONCERNING THE TERMINOLOGY OF SOIL BACTERIA

JACOB G. LIPMAN

The period 1890–1910 has been one of notable progress in soil bacteriology. It is marked, on the one hand, by the appearance of KRAMER'S book[1] and, on the other, by the publication of LÖHNIS' handbook.[2] A comparison of these two works will show not only a rapid increase in the body of facts relating to soil bacteria, but also a series of more or less successful attempts to arrange these facts in an orderly fashion. There have been created in this manner a number of terms that are to designate certain groups of physiological functions or reactions, like nitrogen-fixation, nitrification, denitrification, sulphate-reduction, etc.

As we inquire into the meaning of the different terms thus created, we find much that is indefinite and confused. We find, likewise, that other terms, while definite enough as to their meaning, are too unwieldy for use in the lecture room. For instance, the term "denitrification," already well established in our terminology, is not at all definite. The earlier investigators employed it to designate the reduction of nitrates,[3] irrespective of the fact whether the reduction products were nitrites, ammonia, nitrous oxide, or nitrogen gas. Latterly there has been a tendency to restrict the use of the term to the complete reduction of nitrates, involving the liberation of nitrogen gas, or at most of nitrous and nitric oxides. KAYSER[4] and after him LÖHNIS[5] have attempted to distinguish between complete and partial reduction of nitrates by employing the terms "direct denitrification" and "indirect denitri-

[1] Die Bakteriologie in ihren Beziehungen zur Landwirtschaft. Vol. 1. Wien. 1890.

[2] Handbuch der landwirtschaftlichen Bakteriologie. Berlin. 1910.

[3] GAYON and DUPETIT, Recherches sur la réduction des nitrates par les infiniment petits. Station Agronomique de Bordeaux. Nancy. 1886.

[4] Microbiologie Agricole, p. 117.

[5] Handbuch der landwirtschaftlichen Bakteriologie, p. 447.

fication." It is needless to say that these terms are not only too long, but when taken together with "Nitratreduktion" and "Salpeterassimilation," as employed by LÖHNIS,[6] they are far from removing the existing confusion.

In the same way the terminology relating to the formation of nitrogen compounds by microorganisms out of elementary nitrogen is not at all satisfactory. The terms "Stickstoffixierung," "Stickstoffsammlung," and "Stickstoffassimilation" are used interchangeably in the German publications. The English terminology, with its "nitrogen-fixing," "nitrogen-gathering," and "nitrogen-assimilating" bacteria, is as unwieldy as the German "Stickstoffixierende Bakterien," or the French "microbes fixateurs d'azote." To make matters worse, there has crept into American publications[7] the use of "nitrification" and "nitrifying" as synonymous with "nitrogen-fixation" and "nitrogen-fixing," respectively.

Almost as much confusion exists in the designation of other physiological reactions. One is uncertain in these days whether "methane bacteria" are organisms capable of decomposing cellulose with the formation of methane, or are merely organisms capable of oxidizing methane to water and carbon dioxide. It is difficult to decide, at times, whether the term "sulphur bacteria" refers to the organisms capable of oxidizing hydrogen sulphide partly, or to those capable of oxidizing it completely. Other examples of indefiniteness or confusion may be found in the terminology of sulphate reduction, hydrogen formation and oxidation, and ammonia production and transformation.

The foregoing examples will suffice to show that there is need for more rigid definition and classification in the domain of soil bacteriology. Indeed, this need is so pronounced that the writer has been led to prepare the present paper in spite of his desire not to introduce striking innovations, and in spite of the knowledge that any proposed change in the terminology already existing will be criticized. The writer would add here, however, that it is not his intention to propose any change either morphological or physiological in the general classification of bacteria. It is his wish,

[6] *Op. cit.*, pp. 477–478.

[7] See FLETCHER, "Soils."

merely, to systematize the designations of certain types of physiological reactions, and to arrange them so as to provide for future development. In doing this he has found it necessary to create a few new terms and to modify the meaning of old terms. The proposed arrangement of some of the more important groups of soil bacteria is as follows:

GROUPS OF SOIL BACTERIA ARRANGED IN ACCORDANCE WITH THEIR PHYSIOLOGICAL FUNCTIONS

Ammono-bacteria	*De-ammono-bacteria*
amino-	-amino
pepto-	-pepto
proteo-	-proteo
	-nitri
	-nitra
Nitro-bacteria	*De-nitro-bacteria*
nitri-	-nitri
nitra { ammono-	-ammono
nitri-	-nitrioxy
	-nitraoxy
Proteo-bacteria	*De-proteo-bacteria*
ammono-	-pepto
amino-	-amino
pepto-	-ammono
proteo-	
nitri-	
nitra-	
Azoto-bacteria	*De-azoto-bacteria*
azo-	amino-azo
rhizo-	ammono-azo
	nitra-azo
	nitri-azo
Sulpho-bacteria	*De-sulpho-bacteria*
sulphid-	-sulphite
thio-	-sulphid
Ferri-bacteria	
ferro-	

DEFINITIONS

Ammono-bacteria.—Organisms capable of producing ammonia out of nitrogen compounds.

Nitro-bacteria.—Organisms capable of oxidizing nitrogen compounds to nitrites, nitrates, or both.

Proteo-bacteria.—Organisms capable of transforming nitrogen compounds into protein.

Azoto-bacteria.—Organisms capable of changing elementary into combined nitrogen.

De-ammono-bacteria.—Organisms capable of transforming ammonia into nitrogen compounds other than nitrites or nitrates.

De-nitro-bacteria.—Organisms capable of reducing nitrates to nitrites, ammonia, nitrous or nitric oxide.

De-proteo-bacteria.—Organisms capable of transforming protein into more simple cleavage products.

De-azoto-bacteria.—Organisms capable of liberating elementary nitrogen from nitrogen compounds.

Sulpho-bacteria.—Organisms capable of oxidizing hydrogen sulphide to elementary sulphur, sulphites, or sulphates.

De-sulpho-bacteria.—Organisms capable of reducing sulphates to sulphites or sulphides.

Ferri-bacteria.—Organisms capable of transforming ferrous into ferric compounds.

CORRESPONDING TERMS

Ammonification	Deammonification
Nitrification	Denitrification
Proteofication	Deproteofication
Azotofication	Deazotofication
Sulphofication	Desulphofication
Ferrification	Deferrification

Of the eleven groups of bacteria named above, eight consist of organisms concerned in the transformation or increase of combined nitrogen. The ammono-bacteria consist of amino-ammono, pepto-ammono, and proteo-ammono, according to the source of the ammonia. It will be noted that the first part of the combined term refers to the initial product and the second part to the final product. Thus, proteo-ammono-bacteria are organisms capable of forming ammonia out of protein. It is evident, of course, that a single organism may be able to produce ammonia out of both peptone and protein, and it could be designated, therefore, as pepto-ammono and likewise as proteo-ammono. Similarly, the nitro-bacteria include the nitri- and the nitra-bacteria. The latter in their turn may consist of ammono-nitra and nitri-nitro, the assumption being in this case that there are species capable of oxidizing ammonia directly to nitrates.

The proteo-bacteria would naturally include a large number of species, among them the nitrate, ammonia, and amino assimilating species. While objections will probably be raised against the creation of this very general group, it must be recognized that the terms ammono-proteo or nitra-proteo are more consistent than "nitratassimilierende" or "ammonassimilierende." Moreover, these terms should supplement the term "proteofication," a very compact and logical designation of the transformation of various nitrogen compounds into protein.

The azoto-bacteria should include all of the nitrogen-fixing species. According to the proposed terminology, they would consist of the azo-bacteria, that is, the non-symbiotic nitrogen-fixing bacteria (freilebende stickstoffixierende Bakterien) and the rhizobacteria, that is, *Ps. radicicola*. The azo-bacteria would in their turn consist of *Clostridium Pastoriannum*, *Azotobacter*, and miscellaneous species already known or still to be discovered. The proposed classification is elastic enough to allow the presence in the azo group of azo-ammono- or azo-nitro-bacteria, should it ever be definitely shown that elementary nitrogen may be directly transformed by certain species into ammonia or nitrate. No serious objection should be raised against the proposed use of azoto, azo, and rhizo. They are not only an improvement on the unwieldy terms at present in use, but are quite in keeping with the term azotofication, whose acceptability will hardly be disputed.

Turning now to the terms de-ammono, de-nitro, de-proteo, and de-azoto, we find them to be the opposites of the corresponding ammono, nitro, proteo, and azoto. Just as ammono designates the *appearance* of ammonia, so de-ammono designates the *disappearance* of ammonia. Now ammonia may disappear by being converted into amino-compounds, peptone, or protein; hence, de-ammono-amino, de-ammono-pepto, de-ammono-proteo. Also in this, as in every other case, the first part of the compound term designates the initial and the second part the final product. The terms de-ammono-nitri and de-ammono-nitra were not included in this group, because they properly belong to the nitro group (ammono-nitri and ammono-nitra).

The meaning of de-nitro has been modified to correspond to

nitro. It will be remembered that nitrifying bacteria, according to the accepted definition, are organisms capable of changing ammonia into nitrites and nitrates. If it be true, as it is claimed by KASERER, that there are organisms capable of oxidizing elementary nitrogen directly to nitrates, they should be included under the azoto-bacteria, the true nitrogen-fixing bacteria. Hence, nitrification deals properly with the transformation of nitrogen compounds, more strictly speaking, the *oxidation* of combined nitrogen. Now, since *denitrification* is a *reduction of combined nitrogen*, it should not include processes where *elementary* nitrogen is formed. The latter are the opposite of azotofication (nitrogen-fixation), and should therefore be included under deazotofication. In other words, KAYSER'S and LÖHNIS' direct *denitrification* would become deazotofication under the proposed terminology, and their indirect denitrification would properly become denitrification. The advantages of the proposed arrangement are so evident that further discussion is hardly necessary.

The next group of de-proteo-bacteria would naturally include the organisms of decay and putrefaction, and the term employed here should therefore refer to dissimilation processes. It is evident at the same time that many de-proteo-bacteria would also be proteo-bacteria and *vice versa*. Objection may be raised for this reason to de-proteo, as well as to proteo; nevertheless, because of their supplementing the very convenient terms proteofication and deproteofication, they should be retained.

The group of de-azoto-bacteria would include all species capable of breaking down nitrogen compounds with the evolution of elementary nitrogen. Starting with amino-compounds, ammonia, nitrates, or nitrites, we could have amino-azo-, ammono-azo-, nitra-azo-, and nitri-azo-bacteria. As was already indicated above, the direct denitrifiers would be designated here as nitri-azo- or nitra-azo-bacteria. Similarly, the organisms capable of oxidizing ammonia with the evolution of elementary nitrogen would be designated as ammono-azo-bacteria.

We come finally to the sulpho-bacteria and de-sulpho-bacteria, organisms concerned with the oxidation of hydrogen sulphide and elementary sulphur on the one hand, and of reducing sulphates

and sulphites on the other. The method of classification has been sufficiently outlined above to make it unnecessary to go into further detail here. It should be pointed out, however, that the proposed terminology could be extended to embrace many other physiological functions and reactions. It would be made to include the appearance and disappearance of methane, of hydrogen, of carbon monoxid, of sugars, amino-compounds, alcohols, organic acids, etc. Terms like dextro-propio or dextro-butyro should not be difficult to understand, nor many other compound terms that will readily suggest themselves to the reader.

The writer is aware of imperfections existing in the proposed grouping of some of the species; he feels, however, that in spite of these imperfections his suggestions deserve careful consideration at the hands of his colleagues. Should the present paper do no more than create a critical discussion of the existing terminology his work will not have been in vain.

NEW JERSEY EXPERIMENT STATION
NEW BRUNSWICK, N.J.

BRIEFER ARTICLES

NOTE CONCERNING THE DISCOVERY OF THE NUCLEUS

Historical reviews generally refer the discovery of the nucleus to ROBERT BROWN, perhaps adding that before BROWN'S work the nucleus had occasionally been figured, but that the authors attached so little importance to the structure that usually it is not even mentioned in the text. BROWN himself cites several of these instances.

A quite forgotten paper by F. J. F. MEYEN, published in *Linnaea* (1827),[1] however, gives an account of the nucleus of *Spirogyra*, which for accuracy of observation and clearness of detailed description leaves little to be desired. A somewhat briefer account, similar in essentials, appeared a year later in a little monograph entitled *Untersuchungen über den Inhalt der Pflanzenzellen*.[2] Neither publication being commonly accessible, a paragraph from the latter is reprinted here.

Es wird hier am rechten Orte sein nochmals auf den Inhalt der Zellen, in der Gattung Spirogyra, aufmerksam zu machen. Wir beobachteten nämlich, dass mitten in den Zellen dieser Pflanze ein plattgedrücktes rundes Zellchen, durch äusserst feine verästelte Fäden an der innern Fläche der Zelle befestigt, aufgehängt ist. Es hängt dieses Organ mit den platten Flächen parallel den Grundflächen der Zelle oder des Utriculus der Spirogyra, und zeigt bei der mikroskopischen Ansicht von Oben eine längliche schmale Figur, etwa $\frac{1}{4}$ bis $\frac{1}{3}$ der Länge des Querdurchmessers der Zelle haltend. Das Organ selbst ist fast durchsichtig und ungefärbt; eine grosse Menge von äusserst feine und sich verästelnden Fasern verlaufen von verschiedenen Punkten desselben meistens büschelförmig nach der innern Fläche des Utriculus, woselbst sie sich abermals ansetzen, um jenes Organ, gleichsam wie eine Spinne in ihrem Gewebe, in der Mitte des Utriculus fest zu halten. Es schien mir, als wären es stets 4–6 dergleichen Büschelchen feiner Fasern, die sämmtlich, nach verschiedenen Seiten verlaufend, das Zellchen in der Mitte des Schlauchs befestigen. Die Fasern selbst sind wohl die feinsten, die bis jetzt im ganzen Pflanzenreich beobachtet worden sind, sie sind ungefärbt, durchsichtig und daher sehr leicht zu übersehn. Ihrer grossen Feinheit wegen vermag man bei einer 300 maligen Vergrösserung an ihnen nichts mehr zu beobachten, als

[1] Ueber das Genus *Spirogyra* Lk., und über die Bewegung und Metamorphose der *Sp. princeps* insbesondere. Linnaea **2**:428. 1827.

[2] Berlin, 1828, p. 55.

ihre Verästelung nach der Schlauchmembran zu. Die über dieses Organ gemachten Beobachtungen sind folgende: Durch Einwirkung von Weingeist und kochendem Wasser wird das längliche Organ ganz kugelrund. Auch wird es kugelrund, wenn die Pflanze ihren individuellen Lebenslauf vollendet hat und sich aufzulösen anschickt, alsdann reissen die Fasern allmälich sämmtlich entzwei, und das Organ selbst fällt aus der Mitte zur Seite, und nach Eröffnung der Zelle, durch Fäulniss, tritt es selbst zur Zelle hinaus. Zu dieser Zeit erscheint in jeder kugelförmigen Zelle, wozu sich jenes längliche Organ umgewandelt hat, ein längliches Infusorium, dessen Gestalt wir bei der schon angeführten Abhandlung abgebildet haben. Nach Ausbildung des Infusoriums öffnet sich nämlich die kugelförmige Zelle, und das neue Thier tritt heraus.

Figures supporting the description accompany the paper in *Linnaea*. The earlier paper distinguishes more sharply than the quoted paragraph between observation and interpretation when it comes to the metamorphosis of the organ in question into an infusorium, the author concluding his observations with "So weit meine Beobachtungen," and then proceeds to show that probably the infusoria found about decaying *Spirogyra* originate in the organ described. In view of the prevalence at the time of the doctrine that infusoria take origin in a metamorphosis of decaying plant parts, the attempt to find a connection between the newly discovered organ and the formation of infusoria does not detract from the value of MEYEN's contribution. Nor is the fact that he speaks of the organ as a "cell" of significance, the term being freely used at the time to designate in a general way any globular or vesicular structure, as well as in the more restricted sense.

It is a curious fact that this work of MEYEN's has dropped so completely out of the current of citation. In 1830 he reprinted the account, unchanged in essentials, in his *Phytotomie*, under the heading "Thierbildung im Zellensaft."[3] In the section of his *Physiology* discussing the nucleus,[4] he does not refer to this work, but later on[5] he devotes several pages to it. He has become skeptical whether this organ gives rise to infusoria, but, notwithstanding considerable further study, he was unable to come to a conclusion regarding its nature. SCHLEIDEN had just attracted increased attention to BROWN's work on the nucleus by the important rôle he ascribed to it in his *Phytogenesis*. MEYEN, attacking his rival's theory, used as one of his arguments that the nucleus is lacking in many tissues. Consistent with this line of thought, mini-

[3] Phytotomie, Berlin, 1830, p. 165.

[4] Neues System der Pflanzen Physiologie **1**:207. 1837.

[5] *Op. cit.* **3**:418. 1839.

mizing the importance of the nucleus, he questions whether the organ he described in *Spirogyra* is BROWN'S nucleus.[6]

SCHLEIDEN, intentionally or otherwise, does not mention this work of MEYEN in his *Phytogenesis* nor in the *Grundzüge;* he names BROWN the discoverer of the nucleus, and this statement in these widely circulated publications is to a great extent the source of the current opinion that BROWN gave the first description of the nucleus.—W. MARQUETTE, *University of Wisconsin, Madison, Wis.*

NUCLEAR PHENOMENA IN PUCCINIA PODOPHYLLI

(PRELIMINARY NOTE)

In the mycelium of *Puccinia Podophylli* which is to give rise to aecidia and spermagonia a binucleate condition prevails, the nuclei being associated in pairs and dividing conjugately throughout all parts of the mycelium, even before there is any indication of aecidium formation. This condition, however, is not constant. Uninucleate cells are occasionally observed, while those with more than two nuclei are very common.

The aecidium arises in a dense tangle of hyphae beneath the epidermis of the host. Certain cells in the midst of this tangle enlarge and become the "basal cells" of the aecidiospore chains. Whether any one of these cells is simply the enlarged termination of a hypha or is the product of the fusion of two cells, as originally described by CHRISTMAN for certain aecidia of the caeoma type, is not clear. Appearances have been observed which seem to indicate that such a fusion may occur, but any final conclusion upon this point is at present unwarranted. No migrations of nuclei between cells of the same or different hyphae can be recorded. The young basal cells contain two, three, or four nuclei, which at this stage become very large. The very frequent occurrence of four-nucleate basal cells upon a prevailingly binucleate mycelium is a further indication that such cells may not be of simple origin.

The aecidiospores, which are formed with intercalary cells in the usual manner, contain two, three, or four nuclei, depending upon the number contained in the basal cells from which they are derived. In older chains only two of the basal cell nuclei continue to function in this capacity, so that the binucleate spores finally far outnumber the others.

[6] It is to be noted that vol. I of the Neues System der Pflanzen Physiologie was published a year earlier than SCHLEIDEN'S Phytogenesis.

The nuclear phenomena in connection with spermatium formation have also been examined. The "basal cells" which bud off the spermatia contain one, two, or even three nuclei. These divide mitotically, providing nuclei for the successively abstricted spermatia. A constriction appears near the tip of the basal cell, and the nucleus passes through the narrow portion into the tip, after which the constriction becomes completed, cutting off a spermatium. In no case did the nucleus appear to be pinched into two parts by the constriction. The spermatia vary in length, some of them being more than three times as long as the diameter of the nucleus, so that they contain much besides nuclear material. In several two nuclei were observed.

A full description of the phenomena outlined above, with figures, will appear in a later paper, together with results of further investigation into the origin of the binucleate condition of the aecidial mycelium.—LESTER W. SHARP, *The University of Chicago.*

CURRENT LITERATURE

BOOK REVIEWS

An encyclopedia of microscopical technique

In the exact sciences, as a rule, the formulation of a working hypothesis precedes the discovery of methods for its investigation. In biology, on the other hand, this procedure has been often reversed, for here we frequently find that the whole aspect of a science has been changed as a result of new facts brought to light by methods which have been empirically developed. For example, no one could have foreseen that, if nervous tissues were treated successively with solutions of potassium bichromate and silver nitrate, the resulting precipitate of silver chromate would be deposited almost exclusively on the nerve cells and their processes; nor that the medullary sheaths of nerves after long treatment with potassium bichromate would stain strongly in hematoxylin. Yet these two methods have, to a large extent, made possible the modern science of neurology.

The fact that the element of chance has played so large a part in the development of methods for microscopic investigation is doubtless due in part to the lack of adequate training in chemistry and physics of those engaged in microscopical investigation, and to the lack of interest in microscopical structures of those possessing this training; but it is also due in part to the fact that our textbooks of microscopical technique have, for the most part, described the technical manipulations simply as routines to be followed to attain certain results, assuming that the individual using them did not need to know the nature of the reagents he was using, why they were used, nor what each contributed to the final result.

It is sometimes true that careful adherence to an established routine is the safer course for persons of certain limitations in training, but such persons are necessarily limited in their investigative outlook to the exploitation of new material by means of old methods, or to the uncertain hazard of the accidental discovery of new methods. The road to the discovery of new investigative methods by intelligent and well planned experiments is open only to those who are equipped with a knowledge of the chemical and physical properties of the materials with which they are dealing. In this field of experimentation the textbooks of microscopical technique, with one exception, give us but little help. The exception is MANN'S *Textbook of physiological histology*, in which the problems of fixation and staining are fully discussed from the standpoint of the chemistry of the organic materials under investigation, and of the reagents employed. In this work, however, the limitations of theme and space prevented the general application of this method of treatment to the whole field

of microscopic technology, and it remained for the authors of the *Enzyklopädie der mikroskopischen Technik*[1] to make the attempt to provide a comprehensive treatise, in which the whole field of microscopic investigation would be adequately treated from the technical standpoint, and in which, in addition, the chemical and physical properties of the countless reagents employed would receive attention.

The first edition of this work appeared in 1903, and the recent publication of a second edition indicates sufficiently well how great was the demand for such a book. This new edition has been the subject of a thorough revision, bringing all articles up to date and adding many new articles and illustrations. At the same time, a number of articles have been dropped, and others so shortened that the new edition only exceeds the first by some 80 pages. The arrangement of the articles is alphabetical, as the title indicates, and in each case the most significant word has been chosen as the initial word of the title of the article on a given topic. Synonyms appear in the proper alphabetical order, reference being made in each case to the name under which the descriptive article may be found. Much help in locating the various methods is also given by the excellent authors' index at the end of the second volume. After each article numerous references are given which help to enhance the value of the work.

It is to be regretted that more attention has not been devoted to microchemical methods. For example, for the microchemical detection of iron in tissues only MACALLUM'S older method of treatment with ammonium sulphide receives attention, and no mention is made of his later methods of unmasking organic iron by means of acid alcohol, nor of his methods of distinguishing between organic and inorganic compounds of iron. The methods for the detection of potassium and of chlorides are not considered at all. In a work of such scope, however, it is inevitable that each investigator working in a special field will find certain omissions and defects, but these are of minor importance when one considers the immense wealth of material which the book offers to the working biologist.—R. R. BENSLEY.

Ancient plants

During the last decade paleobotany has become a transformed subject. The development of a technic for the sectioning of fossil plants, and the recognition of the phylogenetic significance of the vascular system have introduced us for the first time to some real knowledge of ancient plants. To the morphologist this new material has been of immense importance, for it has enabled him to check his conclusions as to evolutionary sequence by the records of history. For the general student of botany it has extended his

[1] Enzyklopädie der mikroskopischen Technik. Herausgegeben von EHRLICH, P., KRAUSE, R., MOSSE, M., ROSIN, H., WEIGERT, K. 2. Auflage. Bd. I. pp. 800. Bd. II. pp. 680. Berlin und Wien: Urban & Schwarzenberg. 1910. *M* 50.

perspective of the plant kingdom enormously. It is high time to present this new field of knowledge to a much larger group than paleobotanists and morphologists, and Miss STOPES has undertaken to do this in her little book entitled "Ancient plants."[2]

To write such a book is more difficult than to prepare one for special students, for it involves careful selection of material and a simple style. The former always invites the hypercriticism of specialists; and the latter is in danger of sacrificing accuracy to picturesqueness. However, the book is not written for specialists; and extreme accuracy is not so important as vivid impressions. Miss STOPES has certainly succeeded in accomplishing well the task she set for herself. Judgment may vary as to the selections, but this is inevitable; the brevity of treatment has been criticized, but that was a part of the purpose; the attractive and often very picturesque style, even though it might be accused of misleading now and then, is far better for the purpose in mind than a style that flavors of mathematical precision. Such books are intended to arouse interest, and if they stimulate any one to further study, all possible misconceptions will be corrected.

The chapter headings suggest the general treatment: ii, "Various kinds of fossil plants"; iii, "Coal, the most important of plant remains"; iv, "The seven ages of plant life"; v, "Stages in plant evolution"; vi, "Minute structure of fossil plants—likenesses to living ones"; vii, the same—"differences from living ones"; vii–xvii, "Past histories of plant families"; xviii, "Fossil plants as records of ancient countries."

The book can be recommended to all students of botany who should supplement their knowledge of living plants with some information concerning ancient plants. Certainly no student of morphology can afford to neglect the history of his groups, and this little book will serve him well as an introduction.—J. M. C.

NOTES FOR STUDENTS

Mutations in nature.—Mutations probably occur in nature as frequently, in proportion to the percentage of the seeds which succeed in germinating and developing, as in experimental cultures, but actual proof of such mutation must be always wanting. When a single individual of a hitherto unknown type is seen to differ by some marked characteristic from the associated typical individuals of the most closely related species, the natural inference is that the atypic plant is a mutant. If such a plant is found to reproduce its characters in its offspring, such inference is strengthened, but there still remains the question of possible hybridization, and if that can be satisfac-

[2] STOPES, MARIE C., Ancient plants; being a simple account of the past vegetation of the earth and of the recent important discoveries made in this realm of nature study. 8vo. pp. viii+198. *figs. 122.* London: Blackie & Son; and New York: D. Van Nostrand Company. 1910. $2.00.

torily ruled out, there is the possibility that the form in question is not itself a mutant, but the offspring of a mutant which appeared in some preceding generation. This last question, of course, can never be cleared up in any instance, but is a consideration of no essential consequence. TRABUT[3] reports finding near the city of Constantine in Algeria a spineless individual of the wild artichoke (*Cynara Cardunculus*) in an extensive population of the ordinary spiny plants. While considerable variation is found in the vegetative characters of *C. Cardunculus*, no similar individual has ever been reported before. This plant being wholly unarmed would undoubtedly have disappeared undiscovered had it not chanced to grow within the inclosure about the waterworks reservoir of Constantine. The seedlings of this spineless individual have not yet been grown, but it seems probable that it will breed true. There are spineless varieties of cultivated artichokes (*C. Scolymus*), and the possibility of hybridization is not positively precluded, but is rendered less probable by the facts that none of the latter are grown in the vicinity of Constantine and that the new form seems to be typical *C. Cardunculus* in everything but the spines.

Much more important than this supposed mutant of *Cynara* is the discovery of a new form of *Capsella*,[4] of which a single specimen was found growing among an abundance of *C. bursa-pastoris* at Izeste, Basses-Pyrénées, France. The history of this new species, which is to be known as *C. Viguieri* Blaringhem, parallels that of the celebrated *Capsella Heegeri*, but *C. Viguieri* shows a variation of the capsules in the opposite direction from that presented by *C. Heegeri*. A very large majority of the capsules have four valves of the same general form as those of *bursa-pastoris*, placed at right angles to each other, but the number of valves varies from 2 to 8. Counts of nearly 10,000 fruits, taken at random from plants grown from the seeds of the original specimen, showed the following frequencies: 2-valved, 2; 3-valved, 81; 4-valved, 8450; 5-valved, 301; 6-valved, 288; 7-valved, 24; 8-valved, 16. The new species is normally fasciated, and breeds true to this character as well as to the high number of valves, except when subjected to unfavorable conditions. As grown at Bellevue, France, the leaves of *C. Viguieri* are almost entirely unlobed, while the leaves from a number of pedigrees of *C. bursa-pastoris*, also secured from Izeste and grown under the same conditions, had always the complex lobing characteristic of the reviewer's type *C. bp. heteris*. The author lays particular stress upon the fact that several other species of Cruciferae possess 4-winged capsules. He names several species of *Tetrapoma* which if 2-valved would be classified as *Nasturtium; Holar-*

[3] TRABUT, L., Sur une mutation inerme du *Cynara Cardunculus*. Bull. Soc. Bot. France **57**:350–354. *pls. 15, 16.* 1910.

[4] BLARINGHEM, L., Les mutations de la bourse à pasteur (*Capsella Heegeri* Solms, *C. Viguieri*, n. sp.). Bull. Sci. France et Belg. VII. **44**:275–307. *pl. 6. figs. 10.* 1911.

gidium if 2-valved would be a *Draba;* while the Californian genus *Tropidocarpon* has one species with 2-valves and one (*T. capparideum* Green) with 4. Tetracarpellary cultivated varieties of *Brassica* and *Isatis* are also known. Such instances as these, of the recurrence of similar characteristics in more or less closely related species or genera, support the view that variation is definite or "orthogenetic" rather than entirely fortuitous. The author believes that such facts are directly opposed to the older conception that species, genera, and families have a monophyletic origin. On p. 280 the gametic formulae of the reviewer's forms, *Capsella bursa-pastoris tenuis* and *C. bp. rhomboidea*, are transposed; and on p. 304 the date of the discovery of *C. Heegeri* is stated erroneously as 1907 and 1908, the correct dates being 1897 and 1898.—GEO. H. SHULL.

Geotropism and epinasty.—KNIEP[5] has studied in detail the part played by geotropism and epinasty in the orientation of certain foliage leaves. He makes much use of modified forms of the oblique and intermittent clinostats of FITTING. With these instruments FITTING[6] answered conclusively many questions on the geotropism of orthotropic organs that two or three decades of work with other instruments had left unanswered. Now, KNIEP proceeds to clear up a number of questions in a plagiotropic organ, the leaf.

In the main *Lophospermum scandens* was used, for the medium-aged leaves of this plant show no sleep movement and little tendency to dark rigor; therefore, they are well adapted to experimentation in darkness. When leaf blades of this plant are placed out of their normal rest position, they recover it by growth-bending of the petiole. During the bending the rate of growth of the middle line is greatly increased. KNIEP designates the usual position of the leaf as the *normal horizontal* position. If the plane of the blade is so changed that the petiole end remains in the original plane but the apical end falls below it, the angle it forms with the normal horizontal position is said to be negative. If this displacement continues $-180°$, the leaf is then in the *inverse horizontal position.* By a reverse movement from the normal horizontal rest position a positive displacement is brought about. If this displacement continues $+180°$, the *inverse horizontal position* is reached. If in darkness a plant is so tilted that a leaf blade takes a position of $-1°-114°$, a rapid growth sets up on the morphologically lower side of the petiole (concave bending) and the blade finally acquires its normal horizontal position. If the plant is so tilted that the blade holds any position from $-116°$ to $\pm 180°$, or from $+1°$ to $\pm 180°$, rapid growth begins on the upper side of the petiole (convex bending) and the leaf finally acquires its normal horizontal position. The labile rest position, then, is at approximately $-115°$.

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[5] KNIEP, HANS, Ueber den Einfluss der Schwerkraft auf die Bewegungen der Laubblätter und der Frage der Epinastie. Jahrb. Wiss. Bot. **48**:1–72. 1910.

[6] Jahrb. Wiss. Bot. **45**:675–700. 1905.

When a plant is rotated on an equally rotating horizontal clinostat, a convex curving always occurs regardless of the orientation of the plane of the blade with the axis; this is an epinastic movement. When the plane of the blade is vertical and the midrib horizontal, the leaf is said to be in a flank position; it is evident that there are two flank positions. If a leaf is left in a flank position, the petiole shows both a torsion and a convex bending which finally give the blade the normal horizontal position. By use of an intermittent clinostat which gives repeated 5–15 minute exposures in one flank position followed by equal exposures in the other, all torsion is avoided, but convex curving takes place. The successive flank exposures equalize the effect of gravity and allow epinasty to express itself. By use of the intermittent clinostat, equal exposures between $-45°$ and the two flank positions were given. In this case concave bending occurred, showing that the geotropic stimulus entirely overcame the epinastic; this gives a means of determining the relative strength of the two stimuli. KNIEP puts the question, Can a leaf blade be so oriented on an equally rotating clinostat that concave bending will appear? This is easily accomplished by the use of the oblique clinostat and the combined angles that are possible on it. The great possibility of combinations of angles of geotropic exposure due to variation in obliquity of the clinostat axis and the obliquity of the organ axis with the clinostat axis has been emphasized by FITTING.

This work is the natural outcome of the improved methods that FITTING has given for dealing with problems in geotropism.—WILLIAM CROCKER.

Photosynthesis.—SCHRYVER[7] believes that he has thrown some light on the mechanism of carbon fixation in green plants. He first describes a modification of Rimini's test for formaldehyde. By the test as modified, 1 p.p.m. formaldehyde gave the reaction, and by proper modification, both free and combined formaldehyde can be detected. Rather accurate quantitative estimates can be made in concentrations varying from 1 part in 100,000 to 1 part in 1,000,000. Films of chlorophyll were formed on glass plates by evaporation of ether solutions. Such plates, exposed to light in the presence of moist CO_2, showed a marked formaldehyde test; those similarly exposed in absence of CO_2 showed a slight reaction, and those in darkness none. The formaldehyde in plates illuminated in absence of CO_2 was supposed to be formed from CO_2 produced by the chlorophyll film. He believes the formaldehyde formed makes a rather stable compound with chlorophyll, much as it does with amino-containing compounds. He considers the reaction reversible, and represents it as follows: $\text{Chloro}^{H}_{H}+HCHO \rightleftarrows \text{Chloro}-CH_2+H_2O$. The removal of CH_2O in sugar formation will cause the reaction to move in the sense of the upper arrow, while accumulation of CH_2O will lead to the reaction moving in the sense of the lower arrow. These results agree with the

[7] SCHRYVER, S. B., Photochemical formation of formaldehyde in green plants. Proc. Roy. Soc. London B **82**: 226–232. 1910.

view expressed by EULER that the formaldehyde exists mainly in combination, and show why EWART was able to extract formaldehyde from chlorophyll.

BERTHELOT and GAUDECHON[8] have accomplished some most interesting syntheses and decompositions of chemical compounds by means of the mercury vapor lamp, rich in ultra-violet. All the results indicate the existence of balances in the reactions. Water was synthesized from H_2 and O_2 and decomposed into these elements. Mixtures of CO and O_2 exposed to the ultra-violet produced considerable CO_2. CO_2 thus exposed gave a slight amount of CO and O_2. If phosphorus were also present with the CO_2, a much greater yield of CO resulted, due to the removal of O_2 by phosphorus. If a mixture of CO_2 and H_2 were exposed to the light, considerable formaldehyde resulted. Mixtures of CO and H_2 thus exposed produced considerable formaldehyde. Formaldehyde was decomposed into CO, CO_2, H_2, and CH_4. These results certainly show great possibility in photosynthesis, as the authors use the term, meaning any synthesis by light.

The work suggests the possibility of chlorophyll functioning by transforming the long rays of the red and blue to short ultra-violet rays, which are more effective chemically. This conclusion, however, one should not accept too readily, for GIBSON, working with the leaf, and LÖB, with the effect of silent electrical discharges on solutions of carbonic acid, have shown the possibility of another conception, namely, that the leaf transforms the absorbed light to electricity, which accomplishes the reduction of the carbonic acid to formaldehyde and perhaps the condensation of the latter to sugars. Neither conception is by any means proved; either, however, explains the peculiar fact that red rays (generally ineffective chemically) are very effective in photosynthesis.—WILLIAM CROCKER.

Digestion of sugars.—The tendency to consider enzymes as specific in their activity, and the desire to distinguish enzymes already known and to discover new ones, have often distracted the attention from the more interesting problems in general physiology regarding enzymes. Such a problem is the relation between the enzymes produced by an organism and the utilization of the different substances on which it is able to nourish itself. From this point of view COLIN[9] makes a comprehensive study of the enzyme activities of the mold *Botrytis cinerea* in the group of sugars. The mold was cultivated on various polyoses, and a study made of the transformations in each case. The enzymes in the culture liquid and mycelium after growth on each sugar was then studied. This was followed by an investigation of the relation which exists between the polyose sugars in general and the enzymes produced by the mold. The mold grew well and showed little morphological variation on

[8] BERTHELOT et GAUDECHON, Compt. Rend. Acad. Sci. **150**:1690–1693. 1910.

[9] COLIN, H., Hydrolyses de quelques polysaccharides par C *Botrytis cinerea*. Ann. Sci. Nat. Bot. **13**:1–111. 1911.

a large number of polyoses. It elaborates various enzymes corresponding to each of these sugars; thus the mycelium thriving on glucose contains sucrase, maltase, etc. A given polyose, therefore, is not indispensable.

The sugar enzymes of *Botrytis cinerea* present two distinct types, based upon diffusibility: the invertase type, perfectly diffusible, and the maltase type, strongly adhering to the pulp. The invertase type includes those enzymes which effect the partial hydrolysis of raffinose, melezitose, gentianose, and stachyose. It is necessary to add emulsin for complete inversion. The enzymes analogous to maltase are lactase, trehalase, melibiase, and in general, those which achieve the complete inversion of trisaccharides and mannieotetrose. The cultures may thus be divided into two corresponding types. The invertase type is characterized by the presence of both the hydrolytic products and the corresponding enzyme in the culture liquid. The maltase type is characterized by the absence of enzyme and hydrolytic products in the liquid. It is necessary to powder the mycelium in order to demonstrate the presence of the enzymes of this type. The type of culture on maltase is very much more general in the case of *Botrytis cinerea*. The cultures on trisaccharides show successively both of the above aspects.

The author draws the following conclusions regarding the specificity of the sugar enzymes of *Botrytis cinerea:* invertase acts as a levulo-polyose, in respect to sucrose, raffinose, gentianose, and stachyose; it produces levulose from each of these sugars either by total or partial hydrolysis; he was unable to characterize a melezitase different from invertase; maltase and lactase are two distinct enzymes; the hydrolysis of trehalose is brought about by an enzyme closely related to maltase; emulsin effects the hydrolysis of gentiobiose; melibiase is clearly distinguished from emulsin, the author being unable to separate it from lactose; it was impossible to identify turanase and manninotriase with emulsin; from the evidence furnished by *Botrytis cinerea* there is no reason to distinguish them from maltase or lactase.—CHAS. O. APPLEMAN.

Permeability.—In continuing his studies upon modified permeability, CZAPEK[10] reports some most interesting results on the relation between surface tension and modified permeability as brought about by certain aqueous solutions. Various workers have shown a marked agreement between the surface tension and the physiological effect of aqueous solutions of certain non-electrolytes. Passing up the series of mono-alcohols, each succeeding member is (on mol. basis) about three times as effective as the member below it in reducing surface tension of an aqueous solution and in producing certain physiological effects. FÜHNER and NEWBAUER[11] have shown for the mono-alcohols, esters, and urethanes that aqueous solutions of equal surface tension produce equal

[10] CZAPEK, F., Ueber die Oberflachenspannung und den Lipoid gehalt der Plasmahaut in lebender Pflanzenzellen. Ber. Deutsch. Bot. Gesell. **28**:480–487. 1910.

[11] Archiv. Exp. Path. u. Pharm. **56**:333–345. 1910.

hemolytic effects. LOEB has shown that for the mono-alcohols the same law holds for induced positive heliotropism and for toxic effects in Copepida and Daphniidae.

CZAPEK describes a piece of apparatus by which one can determine quickly the surface tension of a solution. He studied the effects of alcohols (primary, secondary, and tertiary), esters, and urethanes upon the permeability of plant cells to certain solutes such as tannins and anthocyanins. Any aqueous solutions of these substances having a surface tension of 0.68 or 0.69 or less (water considered as unity) rendered the plant cells permeable to the contained solutes. The material studied was leaf cells of *Echeveria*, petiole hairs of *Saxifraga sarmentosa*, petals of *Paeonia*, leaf epidermis of *Tradescantia*, etc. CZAPEK believes that the surface tension of the *Plasmahaut* of the cells used is a little more than 0.68 or 0.69, and that as soon as the surface tension of the surrounding solution is somewhat lower, the solutes in the cell begin to pass out. By this means, he states, the surface tension of the *Plasmahaut* can be measured, just as osmotic pressure can be measured, by the use of the ordinary plasmolytic agents. He believes that the *Plasmahaut* is an emulsion of neutral fats. An aqueous emulsion of fats gives a surface tension of 0.68 or 0.69. Lecithin and cholasterin give lower surface tensions and are assumed not to play any rôle in the *Plasmahauten* studied.

CZAPEK emphasizes the fact that permeability is often modified by agents that lower the surface tension but slightly if any, as weak solutions of acids, chloroform, chloral hydrate, etc. This cannot be explained, of course, on the basis of lowered surface tension of the solution. He believes that in the case of acids it is due to the saponifying action of the acid on the fat of the *Plasmahaut*.

On the whole, the article confirms TRAUBE'S surface tension theory of osmotic movements of solutions through plant and animal membranes. This theory assumes that the movement of the solutions is in the direction of the lower surface tension.—WILLIAM CROCKER.

Alternative inheritance in elm seedlings.—There are two species of elm in England, *Ulmus montana* and *U. glabra*, both called "Wych-elm," and numerous cultivated varieties of unknown origin which are planted about English hedgerows and parks. Several of these latter are so distinct as to have received specific names, but HENRY[12] finds, as the result of sowing 90 different lots of elm seeds in 1909, that only the two species above named breed true. The seedlings of *Ulmus glabra* have a stiff, erect, unbranched stem with small leaves which are opposite throughout the first season's growth; while *U. montana* has the unbranched stem drooping to one side and only its first two leaves opposite, the rest alternate, the leaves being larger and with longer petioles. All the cultivated varieties of elm tested gave mixtures of seedlings

[12] HENRY, AUGUSTINE, On elm-seedlings showing Mendelian results. Jour. Linn. Soc. Bot. **39**: 290–300. *pls. 5*. 1910.

of these two types with respect to the arrangement of the leaves. The Huntingdon elm (*U. vegeta*), commonly believed to be a hydrid, produced 732 opposite-leaved seedlings and 239 alternate-leaved, the expected Mendelian result if the Huntingdon elm is an F_1 hybrid between *U. glabra* and *U. montana*. Other ratios given by different varieties were 245:95 and 310:84, when the parent trees had grown in such situations that their pollination was probably effected by pollen from the same variety. The progeny of a "Jersey" elm, which was probably pollinated by *U. montana*, consisted of 17 opposite-leaved and 19 alternate-leaved, equality probably being "expected." The "English" elm (*U. campestris*) is also an undoubted hybrid, but this rarely produces fertile seeds, though an abundance of samarae are produced; 19 boxes of seeds of the English elm gave no germinations. This sterility and also the appearance of many imperfect flowers in the various cultivated varieties are accepted by the author as additional evidences of hybridity. The author believes that the varieties produced in genera having a number of species are of fundamentally different nature from those in genera including a single species. In birch, oak, lime, poplar, and willow, as in elm, the varieties are hardly to be distinguished from distinct species except by breeding tests. They are generally the result of hybridization, while in the beech and the ash, each of which is represented in northern Europe by a single species, the numerous varieties are of the nature of "sports," whose relationship and varietal value are recognized at once, as in the case of cut-leaved, purple-leaved, weeping varieties, etc.—GEO. H. SHULL.

Geotropism.—ZIELENSKI,[13] working in JOST'S laboratory, has made accurate determinations of presentation, reaction, and critical times, and of the relaxation index in geotropism, using the roots of *Lupinus albus* and *Lepidium sativum*. Use of the clinostat and horizontal microscope renders his methods delicate and accurate, and the paper has the appearance of a real contribution. "Reaction time" is the period (under continual exposure) from the beginning of horizontal placement to the beginning of curvature. "Presentation time" is the least continual horizontal exposure necessary to give curvature at some later time (the organ is on an equally rotating horizontal clinostat from end of exposure to beginning of reaction). "Critical time" is the least exposure that is not entirely nulled by an opposite and immediately following exposure of equal length (organs are on a horizontal equally rotating clinostat after the second exposure). "Relaxation index" is the ratio of the length of the equal individual rotation periods to the length of equal individual exposures (shorter than presentation time), that will not result in summation. Reaction, presentation, and critical times were determined

[13] ZIELENSKI, FELIX, Ueber die gegenseitige Abhängigkeit geotropischer Reizemomente. Zeitschr. Bot. 3:81–101. 1911.

by reaction in more than half the roots, and relaxation index by reaction in fewer than half. The accompanying table from the article summarizes the results:

	Presentation time	Critical time	Reaction time	Relaxation index
Lepidium sativum at 17–18C. .	5.5 min.	6 min.	25.5 min.	30
" " at 25–27C. .	1.5 "	2 "	12.5 "	40
Lupinus albus at 17–18C. .	8.5 "	11 "	46.5 "	20
" " at 25–27C. .	2.0 "	7 "	33.0 "	25

One is struck here by the time demanded for relaxation from an exposure; it is very much greater than reported by FITTING. The author attempted, without full success, to develop a formula by which any one of the critical periods can be calculated from the other three.—WILLIAM CROCKER.

Photosynthesis.—LUBIMENKO[14] finds that there is a light optimum for the production of dry substance by green plants. The absolute value of this optimum is less than that by which the chlorophyll apparatus is able to furnish the maximum of photochemical work expressed in the decomposition of CO_2. By means of monochromatic filters and gasometric determinations, a comparison is made of the action of the different colored rays on the decomposition of CO_2. These results are compared with the action of the same rays on the production of total dry weight. The energy for CO_2 decomposition in colored light depends upon the absorption of the various colored rays by the chloroplasts as well as on their caloric energy. The author objects to the method employed by KNIEP and MINDER and others in determining the influence of different colored rays on CO_2 assimilation, on the ground that they measured the quantity of light falling upon the leaf and not that absorbed by the chloroplasts. The real carbon fixation expressed by the increase in dry weight is influenced unequally by the different colored rays. The maximum increase in dry weight occurs under the action of the blue-violet rays. The yellow-orange rays are inferior to the red rays, and the minimum occurs in the green rays. It is necessary to assume two successive stages in the photosynthetic process. The first is characterized by the decomposition of CO_2 and synthesis of the first organic product. In this stage of the process the plant utilizes predominantly the energy of the red rays of the solar spectrum. The second stage is characterized by the definitive fixation of the first organic product, and the plant employs for this work especially the blue-violet rays.—CHAS. O. APPLEMAN.

[14] LUBIMENKO, M. W., L'assimilation chlorophyllienne et la production de substance seche à la lumière blanche et à la lumière colorée. Rev. Gén. Bot. **23**: 1–14. 1911.

Light measurements.—Following the well known methods of WIESNER, several careful investigations by RÜBEL have largely increased our knowledge of light conditions in alpine and desert regions and at sea. The most prolonged of these studies was made at Bernina Hospice,[15] a station in the Alps with an elevation of 2309 meters, where it has been clearly demonstrated that both the maximum light intensity and the light totals are greater than those for lower altitudes. The minimum light intensity at midday in the Alps is much higher than at Vienna, the ratio being 85:7; while a similar relation exists between the light totals. Other interesting items from the abundant data are the nearly equal values of direct and diffuse light during the growing period, the somewhat increased light intensity after precipitation, and the decidedly greater available light on southern as compared with northern slopes. Many of these data may prove valuable in interpreting alpine vegetation.

Observations made at sea[16] tend to show that the maximum light intensity differs little from those of regions of low altitude on shore, but that the amount of diffuse light is somewhat greater. The characteristic of desert light conditions[17] appears to be the low light intensity both at full sunlight and with cloudy sky, an intensity which increases considerably, however, immediately after rainfall. This must have some influence in modifying the otherwise extremely xerophytic conditions, but the author seems to follow other investigators of light phenomena in failing to recognize the influence of light upon transpiration. —GEO. D. FULLER.

Work at Peradeniya.—The numerous publications issued from the Royal Botanic Gardens at Peradeniya indicate great activity, which naturally expresses itself chiefly in investigations connected with economic plants. T. PETCH, the mycologist, has found a very fruitful field for cultivation; recent *Circulars* dealing with "Brown root disease" (*Hymenochaete noxia*), which attacks several of the most important plants; "A root disease of *Hevea*" (*Sphaerostilbe repens*), the Para rubber plant; "Root diseases of *Acacia decurrens*," a plant extensively used as a wind-break for tea or for "green manuring"; "Root diseases of tea"; and "Cacao and *Hevea* canker." In the *Annals*, the same author has presented a study of *Lasiodiplodia*,[18] showing in a striking way the confusion that has arisen among the subgenera of *Diplo-*

[15] RÜBEL, E., Untersuchungen über das photochemische Klima des Berninahospizes. Viertl. Natf. Gesell. Zürich **53**:1–78. 1908.

[16] ———, Beiträge zur Kenntnis des photochemischen Klimas der Canaren und des Ozeans. *Idem* **54**:289–308. 1909.

[17] ———, Beiträge zur Kenntnis des photochemischen Klimas von Algerien. *Idem* **55**:91–102. 1910.

[18] PETCH, T., On *Lasiodiplodia*. Ann. Roy. Bot. Gard. Peradeniya **4**:445–465. 1910.

dia; and also a study of *Thielaviopsis paradoxa*,[19] recently found to be the cause of a stem disease of the cocoanut palm in Ceylon.

In other *Circulars* issued during the latter part of 1910, E. E. GREEN presents a "Report on the outbreak of *Achatina fulica*," a ravaging snail; M. KELWAY BAMBER and R. H. LOCK discuss "The effect of different intervals between successive tappings in Para rubber (*Hevea brasiliensis*)"; Reports on "Cotton growing in Ceylon" and on "*Cymbopogon* grass oils in Ceylon" are published; and Director J. C. WILLIS presents the first of a series of directions as to "School gardening and nature study." WILLIS[20] has published also the first instalment of a revision of the catalogue of the vascular plants of Ceylon, published by TRIMEN in 1885.—J. M. C.

Effect of strontium salts on algae.—The chemical properties of calcium and strontium agreeing more closely than those of sodium and potassium, one might expect to easily substitute strontium for calcium in physiological relations. Investigations along the animal side have been to the contrary, and LOEW[21] has endeavored to gain further knowledge by tests with species of *Spirogyra* especially. Chemically equivalent solutions of calcium chloride (1 per cent) and strontium chloride (1.7 per cent) were used separately. The filaments remained for months in the calcium chloride practically intact. In the strontium chloride the injurious effects were manifested slowly, but within a month the chloroplasts became yellowish-green, less active in starch-making, and finally the cells died. In the strontium solution needle crystals developed in the cells, something which did not occur in the calcium solution. It appears obvious to the author that such crystals represent a combination of strontium with organic acid. Since the algae endure the strontium salt longer than any other except calcium, it seems that strontium does not rapidly displace from important positions in the protoplasm other metallic elements such as potassium and magnesium. According to the law of mass-action such a displacement would be expected. A discussion of why strontium does not physiologically replace calcium leaves the reader with little to cling to.—RAYMOND H. POND.

Anatomy of Riccia.—Taxonomists separate the genus *Riccia* into two subgenera, *Euriccia* and *Ricciella*. In the former the dorsal region of the thallus consists of columns of cells split at the corners, each 4 columns of cells thus inclosing a long narrow air chamber having no lateral communications; in the latter, flat lamellae bounding the relatively large air chambers. STEPHANI, however, studying *R. vesiculosus*, in which 8 cells bound the air chamber, places this form in the subgenus *Ricciella*, and says: "Dividing the genus into

[19] PETCH, T., *Thielaviopsis paradoxa* (de Seynes) v. Höhnel. *Idem* 511–574.

[20] WILLIS, J. C., A revised catalogue of the flowering plants and ferns of Ceylon. *Idem* 467–510.

[21] LOEW, OSCAR, Ueber die Wirkung von Strontiumsalzen auf Algen. Flora **102**: 96–112. 1911.

two parts is hardly justifiable, where, as this plant shows, intergradations exist."

JUEL,[22] studying *R. Bischoffii*, found that the cells of the median dorsal region of the thallus are arranged according to the so-called *Euriccia* pattern, while the wings have the *Ricciella* pattern; the smallest air chambers being bounded by 6 cells and the largest by 15. He attributes the presence of the 4-sided air spaces of the middle region to the fact that the ventral cells grow a little more rapidly than do the dorsal cells. The increasingly larger air spaces of the wings are due to very unequal growth of the cells. This work is another example of how artificial and arbitrary distinctions frequently break down when the problem is attacked by an observer trained in morphological methods.—W. J. G. LAND.

Traumatotaxy and chemotaxy.—RITTER[23] has published an article on traumatotaxy and chemotaxy of the nucleus. It adds little that is new and is not markedly critical. In the region of the wound the nuclei in the intact cells move toward the wound and enlarge somewhat. Light and gravity do not modify the reaction, while absence of oxygen and anaesthetics entirely stop it. After five or six days the nuclei recover their normal position; this agrees with the duration of the respiratory acceleration due to wounding. There are a number of parallels between the traumatotactic and chemotactic responses, but the author concludes that the chemotactic effect of endosmosing solutes from the dead cells cannot account for any considerable part of the traumatotactic response. The wound response is much more rapid than the response to chemicals; wounds also produce protoplasmic movements, while the chemicals do not. RITTER believes that in the wound response the nuclei are passively transported by the moving protoplasm; on this point his evidence is certainly not convincing. The effective chemotactic substances were salts, bases, organic acids, and carbohydrates. Inorganic acids and many organic substances were not effective.—WILLIAM CROCKER.

Hybrids at Kew.—A list[24] of all hybrids produced in the Royal Botanic Gardens at Kew, England, will surprise many by its shortness, considering the length of time during which Kew has been one of the great botanical clearing houses of the world, and the obvious advantages it has had on this account for the production of hybrids. The earliest hybrid produced at Kew was the result of a cross between *Rhododendron Griffithianum* and *R. Hookeri*, made in 1874; and in the 36 years from that time, until this list was published, 49 hybrids have been produced, and 12 failures are reported.

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[22] JUEL, O., Ueber den anatomischen Bau von *Riccia Bischoffii* Hub. Svensk. Bot. Tidsk. **4**:160–166. *pl. 7. figs. 5.* 1910.

[23] RITTER, GASTON, Ueber Traumatotaxis und Chemotaxis des Zellkernes. Zeitschr. Bot. **3**:1–42. 1911.

[24] Hybrids raised at Kew. Kew Bull. **1910**:321–328.

The largest number of hybrids secured in any one year were 6, produced in 1898. It is disappointing to the hybridologist to find in this list almost no data of any scientific significance regarding these hybrids. The brief comments made in connection with each cross refer purely to the value of the result for decorative or other economic purposes, and no definite comparison is made between the characters of the hybrid and those of its parents, except occasionally in regard to cultural matters.—GEO. H. SHULL.

Position of Gnetales.—LIGNIER and TISON[25] have applied their anatomical methods to the so-called "flower" of the Gnetales, and have reached the conclusion that the group belongs to angiosperms, among the Amentales; and that it probably represents a reduction series derived from the "base of the angiosperm trunk." This carries one back to the old conflict over gymnospermy; and in fact the interpretation of the ovule of Gnetales is almost identical with that of the ovule of gymnosperms nearly 100 years ago, for it reads "un ovaire fermé, prolongé en style et stigmate et ne renfermant qu'un seul ovule réduit au nucelle." This conclusion is a good illustration of the use of selected testimony rather than of all available testimony; an eclectic rather than a synthetic judgment. One might imagine a reduction series resulting in an open ovary, for there are open ovaries among angiosperms; but that such a series could result in the reappearance of such structures as archegonia, etc., is beyond the reach even of scientific imagination.—J. M. C.

Cytase and cytocoagulase.—GRÜSS[26] continues his studies upon gum-formation in the cherry and peach. He attributes it to the action of cytase upon the hemicellulose (especially galactans) of the secondary layer of wood vessels. Quantitative analysis shows 4 per cent of the wood vessels to be galactans. Excessive gumming he attributes to abnormally high cytase action. In the spring, when there is a general digestion of the reserved materials, he could detect a dissolution of the secondary layers of the wood vessels in the neighborhood of the cambium. Cytase was also abundant in this region and the vessels were filled with gum. In autumn he finds in the cambium region an enzyme which deposits an insoluble product from the gum, which gives the reactions of hemicellulose; he calls this condensing enzyme "cytocoagulase." The papers of GRÜSS are thrown together in such a way that careful perusal leaves one in doubt as to his exact meaning.—WILLIAM CROCKER.

Germination.—GASSNER[27] continues his studies on the germination of the South American grasses, the present paper reporting on *Stenotaphrum gla-*

[25] LIGNIER, O., et TISON, A., Les Gnétales sont des Angiospermes apétales. Compt. Rend. Acad. Sci. Paris **152**: 201–204. 1911.

[26] GRÜSS, J., Ueber das Verhalten von Cytase und Cytokoagulase bei Gummibildung. Jahrb. Wiss. Bot. **47**: 395–430. 1910.

[27] GASSNER, GUSTAV, Ueber Keimungsbedingungen einiger südamerikanischer Gramineensamen. Ber. Deutsch. Bot. Gesell. **28**: 504–512. 1910.

brum and *Paspalum dilatatum*. In the former light is not necessary for germination; but it shortens the required "after-ripening" period and increases somewhat the percentage of germination. For complete "after-ripening" 30 or more weeks of dry storage are required. A period in a seed bed at low temperature does not favor germination. In *P. dilatatum* 1 or 2 weeks at 50–60° C. dry storage brings about after-ripening. A period in the seed bed at low temperature is effective if it follows 20–30 weeks of dry storage. In this species light does not favor germination. This paper, as did the earlier one,[28] shows lack of exact analytical methods.—WILLIAM CROCKER.

Embryo sac and embryo of Clematis.—SOUÈGES[29] has undertaken the investigation of the embryo and embryo sac of the Ranunculaceae, the four parts cited dealing with the Clematideae. The general situations in the family are well known, so that the usefulness of the present account consists in the elaboration of the details of a single tribe, presumably to be followed by similar accounts of other tribes. Perhaps there is some over emphasis of a definite sequence of stages in embryo-formation, for cell-successions have proved to be quite variable, and such uniformity as can be observed is probably an indication of the uniformity of conditions in which the successive divisions occur. There is certainly evidence of a lack of familiarity with the literature of the subject.—J. M. C.

The embryo of the Bromeliaceae.—GATIN[30] has investigated the structure of the mature embryo and the germination of representatives of the Bromeliaceae. The three tribes were represented by a species from each of the following genera: *Karatas*, *Billbergia*, *Aechmea*, *Puya*, and *Tillandsia*. The variations uncovered are so considerable, and so doubtful as to their significance, that no general conclusion can be reached. The paper, therefore, is a contribution of facts that may become of service.—J. M. C.

Light a form-stimulus.—DUBARD and BUCHET[31] believe that light intensity determines the nature of the relief configuration of the hymenial surface of *Merulius lacrymans*. In high light intensity the surface shows high irregularly anastomosing ridges and deep depressions. In low intensity the furrows and ridges are less marked, and are arranged parallel to the incident rays of light. —WILLIAM CROCKER.

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[28] BOT. GAZETTE **51**:76–77. 1911.

[29] SOUÈGES, E., Recherches sur l'embryogénie des Renonculacées. Bull. Soc. Bot. France IV. **10**:242–250, 266–275, 509–517, 569–576. *figs. 56*. 1910.

[30] GATIN, C.-L., Premières observations sur l'embryon et la germination des Broméliacées. Rev. Gén. Botanique **23**:49–66. *figs. 32*. 1911.

[31] DUBARD, M. M., et BUCHET, S., De l'action de la lumière sur le *Merulius lacrymans*. Bull. Soc. Bot. France **57**:417–420. 1910.

GENERAL INDEX

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